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ABSTRACT

This publication contains a selection of science education research papers, beginning with an overview of trends in science education cognitive developmental research and theory in the United Kingdom. Papers that follow focus on developments in studies of thinking and reasoning, including work on concept mapping and conceptual change. Closely associated are papers focusing on teaching and learning, including studies on teachers, students, or both teachers and students, relating to verbal and non-verbal classroom communication; effect of teacher background on performance; differences in problem-solving performances; effects of instruction on understanding; and computer simulation as a means to aid concept development. Additional papers are representative of work on attitudes and perceptions. These include use of commonality analysis in analyzing teachers' attitudes and practice toward primary science, medical school students' perceptions of science, study of scientific attitudes of science educators who study scientific attitudes, students' attitudes toward conservation of environment and environmental issues, and others. The final paper uses an analysis of earlier science textbooks to identify a trend away from seeing "nature" as a symbol of performance, such that observed complexities and changes in the meaning of the symbol can be more readily accepted. (JN)

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RESEARCH
IN
SCIENCE EDUCATION

VOLUME 12

A selection of papers presented at the Thirteenth Annual Conference of the Australian Science Education Research Association, Macquarie University, Sydney.

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PREFACE

The thirteenth annual conference of the Australian Science Education Research Association was held at Macquarie University, Sydney, on 20-22 May, 1982. This publication contains a selection of the papers presented at the conference.

The papers begin with an overview of trends in science education, cognitive developmental research and theory in the United Kingdom. Such a beginning provides a perfect backdrop for the Australian research activities as reported in the papers submitted for publication.

The first group of papers that follows the introductory article is about some of the developments in studies of thinking and reasoning, including work on concept mapping and conceptual change. Closely associated with this group is a collection of papers that relates, broadly speaking, to teaching and learning. It includes studies where the focus is on teachers, students or both and relates to classroom communication both verbal and nonverbal, the effect of teacher background on performance, differences in problem solving performances, effects of instruction on understanding and computer simulation as a means to aid concept development. The following group is representative of the wide variety of work that is proceeding on attitudes and perceptions. The final paper uses an analysis of earlier science text books to identify a trend away from seeing 'nature' as a symbol of permanence, such that observed complexities and changes in the meaning of the symbol can be more readily accepted. Recognition of the problematics in the dominant stance normally adopted by science educators should lead to a questioning of the separation of 'man' from 'nature'.

Laurie Rattray-Wood
Peter Ferguson

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SCIENCE EDUCATION, COGNITIVE DEVELOPMENTAL RESEARCH AND THEORY IN THE U.K.

Colin Power

INTRODUCTION

In October, 1981, a Science Education Conference was held at Pembroke College, Oxford under the auspices of ADEPT, UBET and AUCET (i.e., physics, biology and chemistry education tutors in University Departments of Education in the U.K.). Through the medium of extended workshop discussions focussing on three themes, the Conference sought to enable science educators to discuss ways of translating theory and research into practice and to explore the implications of recent work for higher degree and research programs. As such, the Oxford Science Education Conference represents the UK equivalent of ASERA. The three themes dealt with were:

A Cognitive development and science education

B Curriculum studies - interactions between formal and informal science learning

C Historical, sociological and political studies of science education

This paper represents a synthesis of, and some reflection upon, the papers and discussions on the first of these themes.

So far as science education research is concerned, the situation is one where researchers are actively building navigation systems for charting children's minds - while science teachers struggle to build rafts from the driftwood of practice in order to stay afloat.

OVERVIEW OF TRENDS IN THE U.K.

Turning now to the task of synthesising the papers and discussions at this conference on cognitive development and science education. It seems to me that since the seminar at Leeds in 1979 (Archenbold, Driver, Orton & Woods-Robinson, 1980) there have been some interesting shifts in perspective. Firstly, whether it be ripple effect from the loss of empire or going into the EEC, in the UK there seems to be less of the colonial mentality and more a sense of community. The model of colleagues in other cognitive research traditions has shifted, positions being seen now less as mutually exclusive alternatives and more as concerned with different facets of cognition. Each tradition has its own proper questions, methodology and contribution to make. Secondly, the model of the pupil as a 'defective formal thinker' is disappearing with the child now being viewed more as a rational and active seeker of meanings and problem solver. Thirdly, the model of the teacher does not always reflect the constructive changes referred to above. While in some sections of the field, the teacher is seen as a collaborator, in others, the researcher still appears as the missionary bringing the light to the ignorant savages in the classroom.

In terms of the scope of the field, at the moment it is restricted to child development, the age ranges focussed upon being limited to the 9-16 year-old span. The womb-to-tomb conception of life span developmental psychology was not evident, although the cross-fertilisation of Theme B and Theme C might bring this about. Given the theme title, not surprisingly, the papers dealt mainly with cognitive development; although two directed attention to affective development, there was no discussion of psychomotor skill development in science.

While there were some important differences in the frameworks underlying the research reported at the conference, I was struck by what seems to be an emerging consensus. In both science education and science education research, it is important to recognise:

1 The knowledge pupils already have and how it is currently organised into schemata or frameworks. Without some framework into which it can be assimilated, an experience is incomprehensible and, therefore, little may be learned from it. But the frameworks by which students assimilate their lessons may not be the ones certified by the scientific disciplines. Students can often repeat segments of lessons or texts even though they understand them in terms of incomplete, inconsistent or incorrect frameworks. Indeed, they may develop specialised frameworks for maintaining the identity of school science in order to cope with the demands of the teacher and assessment, while retaining their own frameworks for dealing with natural phenomena.

2 The use of frameworks (or assimilation) is a dynamic, constructive process, for there is no way in which children can have stored a framework to fit every conceivable situation. Comprehension and, therefore, learning and memory, depend on bringing to bear an appropriate framework, but even the assimilative use of frameworks must involve constructing interpretations of situations.

3 Schemata or framework change (or accommodation) is the sine qua non of the acquisition of knowledge and development as opposed to the mere aggregation of information. It is difficult but not impossible, to accelerate cognitive development and large-scale changes in the frameworks used by children in explaining scientific phenomena.

Before moving to a detailed consideration of the papers presented, a word of caution. The healthy respect for other frameworks in emerging models of cognitive development may be misinterpreted by well-meaning science teachers and technocrats in the Schools Council to imply that any sincerely held framework is as good as any other. While we ought not to present prevailing scientific theories as truths, we ought not to imply a totally relativistic position. There are good reasons for teaching scientific theories which have been developed over long periods of time, have wide explanatory power, and are progressive in the Lakatosian sense.

THEORETICAL PERSPECTIVES IN HUMAN DEVELOPMENT

In the introductory plenary session, Driver (1981) gave a masterly synthesis of theoretical positions in cognitive development and their implications for science education. Three traditions which contribute to our understanding of learning in science:

1 developmental psychology
2 theories of instruction
3 constructivist psychology

The paper clearly set out the current status of each field, its emphasis (processes, integrated knowledge, personal knowledge) and contributions to science education. Driver suggests that each tradition is based on a different view of the nature of science and of the contribution it makes to children's education. The first gives prime importance to the processes of science and the development of thinking skills. The second tends to be based on a view of science as a non-problematic body of knowledge and a view of science education which emphasises the learning of content and integrated frameworks. The third position emphasises personal and tacit knowledge ('Children's science'), and the development of a set of personal meanings for making sense of daily events and experiences. In talking to her paper, Driver suggested that the misuses of Piaget on theory (cf Groen, 1978) have arisen out of misunderstandings of his main research quest - his concern as an epistemologist with the way rationality develops and with making explicit some characteristic structures of thought. The current status of stage theory was described in terms of three positions, and the criticisms and work of those identified as working within the 'constructivist' tradition summarised. Driver highlighted the importance of context and content of a task on subsequent reasoning and of the implicit theories, particularly the 'alternative frameworks' derived from prior experience on which pupils and adults base their reasonings. My major criticism of the paper would be that the third framework, described as 'theories of instruction', identified with Ausubel, Gagne and the information-processing theorists, has developed much further than the paper seems to imply. The current work of science education researchers like Novak, White, Kellett, West, Fensham and others has taken us well beyond the behaviourist tradition and can contribute to our understanding of the ways in which pupils store and retrieve information, and how this might be facilitated in science classrooms.

Cognitive developmental theorists often tend to be 'affectively blind'. Some light was thrown on personal and affective aspects of learning in science in the next two papers. Head (1981) pointed out that the division between the affective and the cognitive is merely a matter of convenience. All the evidence suggests they interact in a variety of ways. Head reviewed research in three broad areas: the influence on cognitive bias and cognitive styles; the role of motivation and attitudinal factors; and the nature of commitment to personal beliefs and the consequent effects on learning. The contribution that personal development theories can make to our understanding of subject choice, career choice, resistance to learning, motivation, cognitive bias and cognitive style was illustrated. He reminded us that changing one's ideas is not just a cognitive process, but involves having the confidence to dispense with ideas to which one has been committed, to lose for a while that sense of security, and identity, before adopting new ones. We considered too the nature of commitment to science in terms of Erikson's 'active self-examination' crisis and Loevinger's ego development levels. For many boys entering adolescence, the decision to opt for science is often a relatively easy way of coping (foreclosure), while for girls, the decision demands the extensive self-examination of a fairly mature person. During the 'moritorium' phase, many young people reject science because it does not address issues seen to be important.

Ormerod (1981) in the next paper also reminded us that the learner has a complete veto over whether he or she learns at all. He proposed a two dimensional model to exhibit the interdependence of cognitive and affective domains, each described in terms of the Bloom and Krathwohl taxonomies, with the latter extended to include a negative dimension. Once again the key question seems to be that of presenting science in such a way that it sparks the imagination, warrants the commitment and matches the personal development of young adolescents.

The examination of theoretical perspectives for studying cognitive and affective development raised many questions, the key ones being:

1 What are the uses and limits of each model?

2 How do we accurately map what the learner already knows, how it is organised and how it is used?

3 How do structures change as a result of new information and experience?

4 If it is true that there are limits on what children can be expected to do, can we accelerate cognitive development, and if so, how?

5 If it is true that the last thing people will do is to make fundamental change in the structures (including alternative frameworks) by means of which they make sense of their world, how and why do particular structures develop, how can they be changed, should they be changed?

6 How can one promote the extension, differentiation and, if necessary, the reorganisation of existing frameworks?

7 Are learning problems in science content and context dependent, or are there principles of development which underlie the specifics?

8 If problems are content dependent, how can we sequence and present material to promote specified learning?

9 Are there some big issues which demand long term research programs and the development of carefully articulated theoretical frameworks?

10 How can we expand and develop the cognitive structures of beginning teachers, experienced teachers and curriculum developers in order to take into account the insights gleaned from recent work in human development as it relates to science education?

The next two papers dealt with epistemology and prior knowledge, further broadening our theoretical perspective. Gilbert (1981) suggested that the epistemology underlying the 'alternative framework' perspective embodies a view of science which approximates to that of Lakatos (1970). He proceeded to outline a 'Lakatosian' research program for the alternative conceptions field. Sutton (1981) presented a strong argument that cognitive development should not be studied alone in isolation from wider questions about the history of thought in the scientific community. He argued that our efforts to study how children extract meaning from their experience and how that meaning can change (the growth of private understandings) can be illuminated by a study of the private insights of the past and what happened to them in the growth of public knowledge.

The lively discussion session which followed the above papers brought us back the central questions raised by Driver: the problems of determining what the student knows, and the problem of conceptual change. On the first Driver described the work she has been doing on pressure using taped interview techniques. On the second, she suggested that students often hold two theories, and that they may understand the theory presented in class, without necessarily believing it. She stressed that children's understanding is often embedded in a context (eg. pressure learnt in context of a collapsing can, sucking) and the role played by imagination in concept change as opposed to conversation in corroboration of theories. Riegel (1973) in a Kuhnian vein,

has suggested that conceptual change on a large scale is a dialectical process which entails a confrontation with difficulties in one's current framework and coming to appreciate the power of an alternative. The problem of conceptual change led to a discussion of the difficulties children face in coping with uncertainty and how we help students to make use of, and not to be daunted by, the uncertainties and stresses generated which we find existing frameworks no longer satisfy our curiosity or accommodate new experience.

EMPIRICAL STUDIES OF CHILDREN'S UNDERSTANDING

Having raised a number of significant theoretical issues and examined contemporary theories, we turned to empirical studies of particular learning problems in science. Shipstone (1981) gave us a concrete example of a study within the 'alternative framework' tradition in his analysis of pupils' understanding of basic electricity from first to lower sixth form. The paper makes a significant contribution to our knowledge of the nature and extent of one very important erroneous model - the 'sequence' model of electricity. According to this model, current leaves one terminal of a battery with a certain strength determined by something in the battery. As the current progresses around the circuit, it responds to each element it encounters in turn. Thus when it reaches a resistor, the effect must be to alter its strength. The model is retained by upwards of 40% of sixth formers, presumably because it is concrete and because pupils are normally successful with problems if they break them down into steps. Shipstone hypothesises that the origin of the model lies in the way we normally describe current flow to pupils.

Equally stimulating was Wood-Robinson's (1981) analysis of children's understanding of the relationship between three dimensional structures and the plane sections through them. He presented convincing evidence of the folly of expecting 14 year olds to interpret the types of 3-D structures commonly found in biology (geology and other sciences) textbooks - a classic case of mismatch. The study investigated pupils' (ages 9, 11, 13, 15 and 17) understanding of sectioning of a wide variety of structures ranging from simple geometric shapes of complex biological structures. The results showed no sudden attainment of the skills of geometric sectioning, that the orientation of the solid is of crucial importance, and that younger pupils who adopted an appropriate strategy when dealing with simple solids, abandoned this when dealing with more difficult shapes. Finally, Wood-Robinson suggested that more concrete sectioning in appropriate contexts would help to reduce the problem. Some changes in the diagrams used in biology texts would not go astray either! Once again the paper provoked a stimulating discussion as participants asked about the effects of sex, experience in sectioning in other areas (eg. woodwork) as well as those factors (task, orientation, age) investigated.

Whereas these two studies directed our attention to particular processes and concepts of concern to science educators, McGuire's (1981) presentation contributed to the question of how we can go about the task of investigating pupils' understanding of scientific concepts. He described three techniques each illustrated with reference to a particular concept. These were:

Method 1: The binary tree technique using an Apple micro-computer (concept investigated: element)

Method 2: The continued free word association test using the stimulus words from the theoretical scientific model (model investigated: atomic structure)

Method 3: The categorisation of instances test using a grid (5 x 5) of instances and non-instances of a concept (concept investigated: momentum).

Not only do the techniques described add to our arsenal of weapons for studying cognitive structures in science, but they can be used by teachers to map pupils' understanding and diagnose weaknesses.

WHITHER SCIENCE EDUCATION?

The final formal paper returned to the consideration of broad theoretical issues and the contribution of cognitive developmental research to science education. Where Driver clearly set out where we are now, Shayer (1981) painted some bold scenarios for the future. He began with a critique of his own earlier work as part of the CSMS program in which he analysed children's cognitive development and the curriculum and which led to conclusions such as that the Nuffield O level courses were well adapted to the rate of cognitive development only of the top 5% of the pupil population.

The underlying model of CSMS work assumes Piagetian tests do test cognitive development. Shayer presented evidence which, he claims, supports his rejection of an alternative interpretation of the CSMS work viz. that the Piagetian tests measure pupil grasp of concepts they have learned and not cognitive development. The evidence presented was not, however, conclusive as Driver and others were quick to point out. A consideration of the third position viz. that the results merely show there is much room for further progress in schooling, led to two scenarios:

1 The classical Piagetian position that attempts to accelerate the rate of cognitive development in the context of science education may increase pupils' understanding of science, but would make little difference to the natural process of development (I am reminded of Piaget's scathing attack on what he called the 'American fallacy').

2 Cognitive development can be accelerated and science education is a good medium for carrying it out.

Shayer described several intervention studies ranging from algorithmic training within science to the ambitious intervention reported by Feuerstein in Israel which aims at cognitive acceleration. On the basis of the remarkable results reported by Feuerstein, Shayer argued that intervention strategies should be prolonged and planned according to some integrated theory of intellectual functioning, rather than being made up of short, sharp, specific training - hence the rationale for the CASE project.

Finally, Shayer suggested that the 1960's have left us with many untested myths about the aims of science education. We are uncertain he claimed:

> Whether to teach for the 'facts', the content of the subject, the conceptual structure of the subject, or the process of science which can be thought <u>through</u> scientific investigations.

It is also uncertain whether science <u>does</u> develop thinking or, if it does, which of the three aims would best assist that process.

In the final session, the group looked at the aims of the conference and asked how well these had been achieved. While there was some hesitancy about

whether research in the field has a great deal to say to teachers just yet, there seemed little doubt that the potential to contribute is there, in terms of new frameworks for thinking about the ways pupils develop, the teaching of particular topics and tools for assessing student understanding.

How to communicate the ideas and results reported to preservice students, and science teachers seems to pose a major problem. Surveys of School Science Review readers typically show that teachers place little value on the types of research reported. It may be, as some suggested, a matter of form and language used - we may need more 'middle men' to integrate and translate the results of the research into a form which captures the attention of, and provides information digestible by, teachers. It may be that STEP needs to be rewritten, for it is what students and teachers do, the experiences they have in working through the tasks and engaging them in research into students' understanding that may in the end have the most lasting impact. After all, if we take the theoretical models discussed seriously, and apply them to teachers as well as children, we cannot expect the mere presentation of information in the Research and Development and Development mode to have much impact on the cognitive structures which guide the activities of teachers in the classroom.

Another problem to which we returned lies with the nature of the teaching -learning problems to be investigated. We wondered to what degree the results of our research are context and content dependent, and to what degree they are generalizable. If the former, then we and teachers will need to go through syllabuses with a fine tooth comb, topic by topic - and we will have no shortage of potential thesis topics for our research students. But, if research from teachers is to be of lasting value, then those engaged in 'action research' will need a great deal of support from universities. It may be too that the word 'research' when applied to the science teacher carried a false expectation. Perhaps the type of training provided in Masters level programs is, or should be, more concerned with providing the expertise needed to solve problems at the school level and stimulating the long term involvement of science teachers in the process of curriculum development and evaluation. If the latter, then we face long term programmes and collaborative efforts, and the problems of helping others to accommodate and assimilate the ideas and results produced. But then, maybe there are probably enough big issues and small, content and context dependent problems to keep us all occupied for some time to come.

CONCLUSION

In the papers presented one can detect a number of major areas of concern.

The theorists like Shayer are largely concerned with the development and refinement of frameworks for studying cognitive development. Their ultimate purposes varied from reconstructing the entire field of science education, to accelerating cognitive development, to changing the 'alternative frameworks' of children. In essence, they seek to tailor the teaching-learning process in accordance with a theoretical blue print.

Those who see the problems as more content and context specific would prefer to chip away at particular topics which create teaching difficulties, thereby contributing to the improvement of practice in a more direct, piecemeal fashion. They could perhaps be described as tinkers. So we have tinkers and tailors.

The soldiers amongst us would equip teachers with the weapons needed to attack their own problems directly. They are working away at developing techniques

for mapping understanding and diagnosing weaknesses in existing structures.

Oh yes, the spies are the moles like me who are concerned with uncovering the secrets of classroom life, with identifying the structures, patterns and processes which characterise classroom interaction, and with the describing and monitoring the 'theories in action' and strategies which skilled practitioners have evolved to cope with the problems of promoting cognitive development in classroom settings.

The ultimate question then, is what contribution can the tinkers, tailors, soldiers and spies make to science education?

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A COMPARATIVE CRITIQUE OF SEVERAL METHODS OF COLLECTING DATA FOR COGNITIVE MAPPING

Peter J. Fensham, Jan Garrard and Leo West

In several earlier papers West and Fensham (1979), West (1980) and Fensham, Garrard and West (1981), we have reported on cognitive mapping by several groups of learners in senior secondary or university classes for chemistry. These maps have been based on propositional learning as the central intention of these classes.

The propositions have primarily been those of the learners themselves, but in some of the studies, use has been made for comparative or learning purposes of the teacher's intentional set of propositions. In most of the maps, learners cluster several propositions together as closely related and hence as being less closely related to others of the propositions that belong to a given content field of knowledge. These clusters and the more isolated propositions have been referred to as nodes. In some of our mapping we have encouraged learners to relate other things from their learning or learned experience to these nodes. For example, West, Fensham and Garrard (1982) report maps for learners in the field, 'amino acids and peptides' that add intellectual skills and examples to the map of learned propositions.

In our endeavours to use cognitive mapping for research into learners' cognitive structures and into its potential as part of the teaching/learning process, we have tried a number of techniques to achieve maps. This paper reports on our experience with these techniques for two purposes.

I Gathering data about the way learned information is stored and organised.

II Gathering data about the nature of the connections of relationships that learners perceive in their stored knowledge.

Our experience for these two purposes are now separately reported.

I THE STORAGE AND ORGANISATION OF LEARNED INFORMATION

The existence of the intentional propositions in a learner's cognitive structure can be checked by a straight forward achievement test. We have used sentence completion with university students and declared recognition with secondary students for whom the purpose of the mapping was to enhance learning. The sentence completion is useful since it also provides a direct indication of the form of the learner's propositional knowledge in the content field.

After this propositional knowledge has been identified, three techniques have been used to get at storage and organisation.

A In this technique, the propositions are identified by a set of key words and presented in pairs to the learners who then indicate a score (0-3) for the amount of relationships they perceive between each pair. Table 1 gives a set of intentional propositions and the presentation for scoring them as pairs. The content field is Standard Measures for Chemicals (covered in four lessons at year 11).

B A variant of this technique is matrix completion in which the learner is asked to record the degree of relationship in the squares of a half matrix that presents all the possible pairings that were in the list of the first technique. Figure 1 shows the matrix form for the set of propositions in Table 1. From either of these sets of scores provided by learners, the researcher can then construct a hierarchical or concentric map which features nodal clusters of propositions and more isolated propositions that are singular nodes as far as the presented set of propositions is concerned.

C The learned propositions are represented by key words that are written on small cards (approximately 40 x 20mm). The learner is then asked to arrange the cards on a two dimensional board in a manner that corresponds with how that learner understands them in his/her own knowledge.

Magnetised cards and a metal board have also been used for displaying maps to groups of students and for modifying maps or developing alternatives through discussion with groups or individuals.

Experience and Discussion of Purpose I

'Experts' such as the Monash University teachers with whom we worked (N about 10) seemed able to sort cards and find the flexibility of this technique helpful. The scoring of the relational pairs and the matrix were too rigid for these persons whose extensive knowledge makes it hard for them to allocate scores across the range of relationships.

First year undergraduate students at Monash (N about 25) in general were able to handle the matrix quite readily and used a wide range of scores. The secondary students in our study (N = 20) were not sufficiently familiar with the format of the matrix to use it. They were, however, able to score the list of relational pairs without difficulty. Card sorting was not a help to the secondary students who seemed to become too fixed on their early positions for the cards. The undergraduates on the other hand found scoring via lists or the matrix (preferred because of its spatial presentation of the scores) the better thing to do first, but having done this they found card sorting a useful visual focus to assist their ascription of relational statements.

Cronin, Dekkers and Dunn (1982) have also used the list of relational pairs with secondary students and found it was easy for them to use.

TABLE 1 Intended Propositions for Four Year 11 Lessons on Standard Measures for Chemicals.

1. A mole is the number of units (atoms or molecules) in the relative atomic or molecular mass of a chemical substance expressed in grams.

2. A compound is a pure chemical substance that contains more than one element.

3. The elements are the basic chemical substances from which all other substances are composed.

4. The Relative Atomic Mass of an element is the mass of an amount of that element relative to the same amount of carbon as standard with C = 12.

5. The element carbon (C) is used to provide a standard for other elements and is given a mass value of C = 12.00 for one of its isotopes.

6. The Relative Molecular Mass of a compound is the sum of the relative masses of the amounts of the elements of which it consists.

7. The Weight % Composition of a compound is an expression of the masses of each element it contains relative to its total mass multiplied by 100.

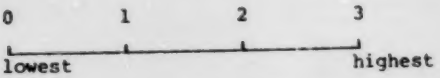
For the following pairs of propositions indicate the degree to which you know them to be related.

Possible degree of relatedness

None or very low	0
low	1
clear	2
very high	3

	Degree of Relatedness		Degree of Relatedness
Mole/Weight % Composition	_____	Compound/Element	_____
Mole/Compound	_____	Compound/C=12, Standard	_____
Mole/Element	_____	Compound/Relative Atomic Mass	_____
Mole/C=12, Standard	_____	Compound/Relative Molecular Mass	_____
Mole/Relative Atomic Mass	_____	Element/C=12, Standard	_____
Mole/Relative Molecular Mass	_____	Element/Relative Atomic Mass	_____
Weight % Composition Compound	_____	Element/Relative Molecular Mass	_____
Weight % Composition/ Element	_____	C=12, Standard/Relative Atomic Mass	_____
Weight % Composition/ C=12, Standard	_____	C=12, Standard/Relative Molecular Mass	_____
Weight % Composition/ Relative Atomic Mass	_____	Relative Atomic Mass/ Relative Molecular Mass	_____
Weight % Composition/ Relative Molecular Mass	_____		

Fill in your estimate of the degree of relationship for each square in matrix.



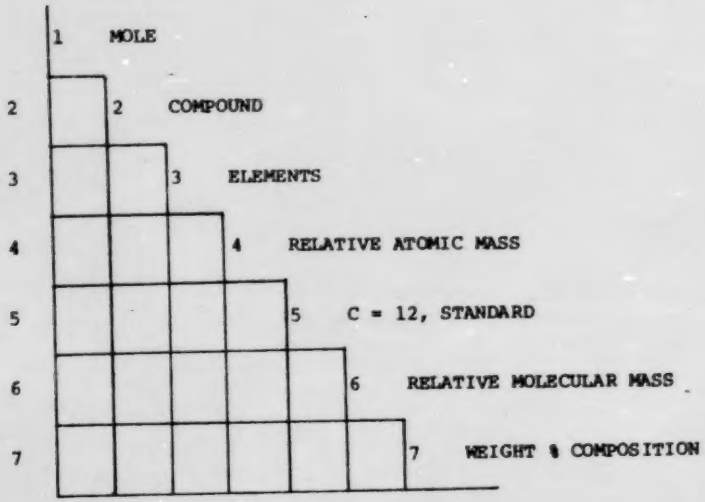


FIGURE 1. Relational values matrix

II RELATIONSHIPS IN STORED KNOWLEDGE

When a map or an arrangement of associations has been achieved by the learner for the propositional knowledge under review, a new stage in the representation of his/her knowledge or understanding is entered. This is the endeavour by the researcher to enable the learner to account for the associations that the learner has acknowledged. We have used two different approaches to the collection of these data.

The first is a direct onslaught on the map's network or relationships. The learner is asked to describe the nature of the associations, that is, to answer the questions. What is the relationship between these? We have tried both an open-ended approach and the choice from a list of alternatives. In the open-ended form, the learner writes or says a phrase or words that are descriptive of the perceived relationship. These may subsequently be rephrased, where possible, to a set of synonymous meanings by the researcher for comparative purpose either with the teacher's intended map or with other learner's maps. When a list of relational descriptions is presented, the learner chooses, if possible, the most appropriate one as his/her description for each perceived relationship. A list of descriptions (for the proposition in Table 1) is given in Table 2.

The second approach involves an interview. The interview is based on the nodes of learner's maps rather than its connections or relationships. It focuses in turn on each nodal proposition or each nodal cluster of propositions. The pattern of the interview has been developed with strong influence by the 'clinical interview' of Pines, Novak, Posner and Van Kirk (1978). This extension of Pines (1977) doctoral work provided detailed instructions for the conduct of an interview.

The particular use of the interview under consideration here is to elucidate the relationships in the map and, 'elucidatory' may be an appropriate name for this particular modification of the clinical interview. (These interviews are also used by us to explore the 'node compression' that has occurred when a learner agrees to use these propositions as 'signposts' for his/her cognitive map of the content fields. (See West, Fensham and Garrard, 1982).

Using the Pines terminology the researcher has to learn to deal with inflexible and flexible parts of the interview. The inflexible parts are as follows:

(i) Establishing rapport.

(ii) Setting the scene of the interview including the arrangements for recording.

(iii) Declaring the content field by the researcher and its acknowledgement by the learner.

(iv) The researcher beginning the interview with, 'I would like you to tell me about Proposition 1 - how you understand its meaning and its connections with other things you know'. (The same type of elucidatory interview has been used about phenomena, objects, examples and problems that form parts of cognitive maps (West, Fensham and Garrard, 1982).)

TABLE 2. List of Possible Descriptors for Relationships in the Field.

STANDARD MEASURES FOR CHEMICALS.

Measure of	Quantifies
Measure for	Example of
Standard Reference for	Made from
Equivalent to	Consists of
Number in	Parts of
Alternative to	Representation of
Analysis of	Symbolic form for
Expression of	Component of

After these inflexible parts, the researcher's contributions are the flexible parts of the interview. These are essentially of two types. The first and more difficult for the researcher involves judgment about how much to encourage - 'I see'. 'Go on', 'And so' - statements which appear to be moving the learner out of the content field. When the judgment, 'Enough', is made, the researcher invokes the prompt, - 'Can we go back to "Proposition 1"?' - the second type of flexibility, and refocuses the learner - 'When you were talking about Proposition 1 a moment ago, you mentioned "Proposition 2" or part of it, can you say more about that?' 'How are they related?'

A schematic pathway for the elucidatory interview is shown in Figure 2, where vertical arrows represent direct references by the learner to the propositional nodes and diagonal arrows to responses that appear to move 'outside' the cognitive map.

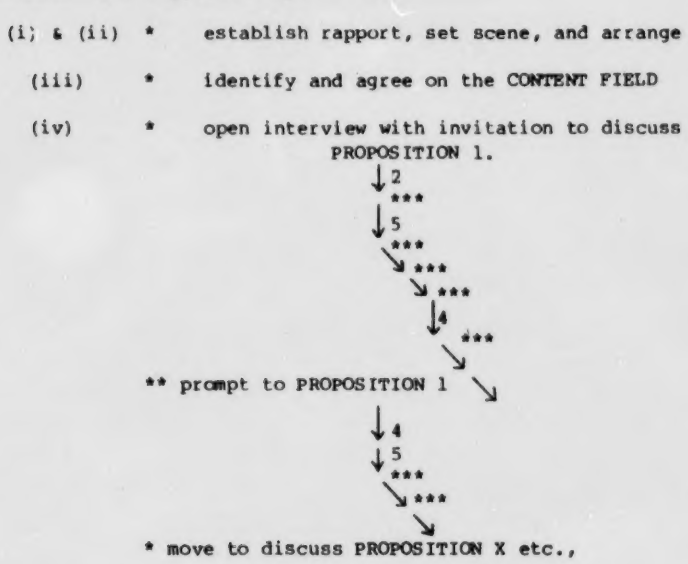


FIGURE 2. Schematic pathway of an elucidatory interview.

* represents the inflexible parts of the interviewee's role
** represents the use of a flexible prompt
*** represents the use of flexible encouragement

When Proposition 1 is exhausted, the researcher begins again with Proposition X, another node in the learner's map.

Experience and Discussion of Purpose II

Our experience with these two approaches can be summarised as follows:

1 Direct The open-ended identification of the nature of the relationship is difficult for secondary learners; usually only about 25% of them can be described. It is not so difficult for most university students who can find descriptors for about 75%. University lecturers (the teachers) find it difficult because they have too many ways of describing most of the relationships.

The choice from a list of alternative descriptors for relationships was very difficult with secondary learners, and difficult for the university students. It was easier for the university lecturers who could choose a descriptor as synonymous with one of their understandings though not necessarily agreeing that they would use those words. For the students it was as if the list was a set of new knowledge that they had not yet met.

2 Interview Our experience of the interview is at this stage largely confined to undergraduates and university teachers. Both these groups are able to respond well to the interview and valuable data are obtained. The greatest problems of this procedure lay with ourselves, since it is not easy to maintain openness and to judge when to move the interview back to its expected pathway. The interview can reveal in a remarkable way the richness of the knowledge structure of some individuals and the way knowledge is connected or held in isolation from what seem to be bits of knowledge that have obvious and intended relationships. With university lecturers the elucidatory interview has given much evidence of the vast store of connected knowledge from which these persons have to select, as West (1980) has pointed out, in their presentation to learners.

It also reveals how much these lecturers draw for their understanding of the intentional learning on knowledge that is certainly not available to the learners and may in fact be several further 'years' of study away.

These findings are interesting to relate to some other data. Symington and Novak (1982) report success for the open-ended approach with primary age children. In this case there was probably less inhibition about articulating descriptors, because there were not preconceptions about what should be learned or about 'correct' answers. In upper secondary these inhibitions were very evident. The relationships have not been described or defined directly by the teacher, so they remained nameless and inarticulate despite the sense the learners had acquired that these propositions belonged together. The list of synonyms was also new, not part of what had been taught or learned. Heffernan (1980) in an interesting study of a proposed hierarchy of 'understandings' or cognitions, found that senior secondary students rated 'explaining the relationship between concepts' as harder than general problem solving that involved the same concepts. They said this was not something that had been taught explicitly by their teachers. Problem solving often meant not only the application of rules that did involve pairs of concepts, but understanding the nature of this connection or its articulation was not required.

SUMMARY

Cognitive mapping by learners for various research purposes is assisted if the appropriate technique is used with learners at different stages of schooling and with varying degrees of understanding of a content field and of related content fields. There are however, techniques now available which appear to be usable by learners in primary, secondary and tertiary education.

The use of the elucidatory interview is an exciting new tool for science educators. It is not, however, an easy one to use and our own experience suggests that a challenging combination of experince and naivety is needed for it to have optimal benefit as a means of rich data.

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A PROCEDURE FOR USING AND EVALUATING CONCEPT MAPS

Patrick J. Cronin, John Dekkers and Jeffrey G. Dunn

INTRODUCTION

Concept mapping as a technique for assessing and representing a learner's cognitive structure has now been used by science education researchers for a number of years (Moreira, 1979; Stewart, Vankirk and Rowell, 1979). However, it has been through the work of Novak and co-workers that concept mapping has recently emerged as a learning/teaching strategy (Novak, 1981). Novak describes concept mapping as

> a process that involves the identification of concepts in a body of study materials and the organisation of those concepts into a hierarchical arrangement from the most general, most inclusive concept to the least general, most specific concept.
>
> (Novak, 1981, p.3)

In this approach students prepare free diagrams in which the concepts are related to each other through propositional statements as shown in Figure 1. The propositions represent the relationships between concepts. In terms of Ausubelian theory the acquisition of relationships between concepts is central to the process of meaningful learning (Ausubel, 1978).

The use of concept mapping in science instruction is now well documented and the approach appears not only to assist student learning of concepts but also has motivational value (Novak, 1981; Williams, 1982). However, the quantitative procedures for evaluating concept maps does not appear to be well developed.

This paper presents details of a new procedure for constructing and evaluating concept maps. The procedures were developed over a one year period and concerned the use of concept maps to revise chemistry topics for students preparing themselves for TAE (matriculation) chemistry in Western Australia.

DEVELOPMENT OF AN ALTERNATIVE CONCEPT MAPPING PROCEDURE

Development Procedure

In the development of a typical concept map, the first step is to choose a suitable stand-alone topic and then to identify the concepts which make up that topic. We chose oxidation-reduction theory because it is a relatively new topic in upper school, is very abstract in conceptual form, and is usually taught as one section of the syllabus.

Some twenty key concepts were identified both by discussions held with chemistry teachers and after an examination of texts. These concepts were then presented to trial groups (typically 8-10 students) who used the concept list to construct a concept map using the method of Novak (1981). In summary this involved the following steps: ranking of concepts in order of 'most

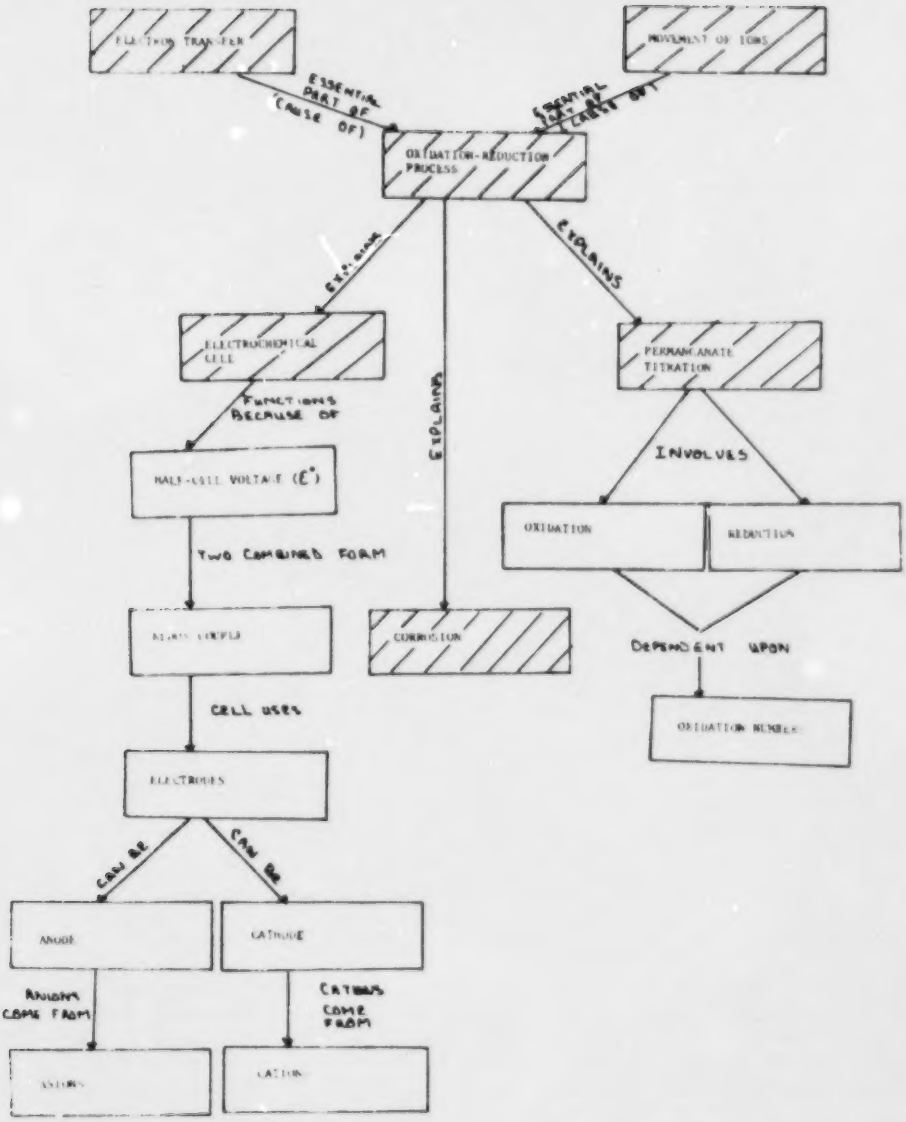


FIGURE 1 Topic: Oxidation-Reduction

important' or generalisable concepts to the 'less important', more specific concepts; linking related concepts with link-lines; and then relating the concepts by propositional statements. After completion of the map, students were interviewed in an attempt to probe their constructional strategy, and also to isolate particular methodological problems.

A similar procedure was carried out with tertiary chemistry teachers who had a specific interest in oxidation-reduction theory to provide a comparative map, and also in an attempt to acquire an 'idealised' map.

The maps were then scored by a group of science educators using Novak's criteria, namely: hierarchy, concept branching, cross linking and propositional statements (Novak, 1981).

Observation of implementation of the scheme by students, together with interview feedback indicated a number of problems which resulted in revisions of both the mapping and scoring procedures. Major problem areas regarding student construction of a map were as follows:

1 A need to assist students to establish a hierarchical structure
It is recommended that concept maps be prepared so that they have a hierarchical structure (Novak, 1981). However, students often find it most difficult to arrange a list of more than about 10 concepts on a scale ranging from the most general and inclusive concept to the most specific concept. In order to assist students in this task a modification of a procedure devised by Fensham, Garrard and West (1981) was used. In this procedure the total number of concepts to be mapped is divided into two lists, called First and Second Column concepts. The First Column consists of up to eight concepts randomly chosen from the total list of concepts. The Second Column contains the remaining concepts. An example of First and Second Column concepts for oxidation-reduction theory is shown in Figure 2. A hierarchical structure of the map is achieved through an associative pairing of the First Column concepts. Each pair is scored on a relative strength-of-relation scale, and the scores for each concept totalled (Figure 2). The concept with the highest score is considered as the most general, all-inclusive of the First Column concepts.

2 A need for space to construct the map
When A4 paper was used, there was insufficient space for the student to develop the spatial arrangement of concepts in a meaningful way. The use of a 60 x 40 cm sheet of paper overcame this problem.

3 A need to allow alteration of the position of concepts on a map
As the concept map develops, it is sometimes necessary to move the positions of concepts within the structure. The use of pre-typed stick-on-labels assisted in this process.

Procedure Adopted

The procedure finally developed for the construction of a concept map was administered to 15 classes at seven different high schools involving 310 students. In the construction of the map, students are provided with an instruction sheet as shown in Figure 2; a large sheet of paper (60 x 40 cm) containing ruled lines 10 cm apart; a sheet of labels which contain both First and Second Column concepts. The first task for the students is to pair First Column concepts in terms of the extent that concepts are related to each other. This is achieved by numerically scoring the relatedness from very related (3 points) to not related (10 points). A summation is then made of

20

A CONCEPT MAP is to be prepared from the oxidation-reduction concepts listed in the FIRST and SECOND COLUMN

FIRST COLUMN	SECOND COLUMN
electron transfer	cations
oxidation reduction process	anions
corrosion	redox titration
permanganate-titration	oxidation
electrochemical	reduction
movement of ions	electrolyte
	equilibrium
	anode
	cathode

FIRST TASK

The KEY IDEAS from the first column are listed in pairs. Score each pair as follows:

They are not related = 0 They are slightly related = 1
They are quite related = 2 They are very related = 3

oxidation-reduction process ------ permanganate titration = ___
electron transfer ------ movement of ions = ___
movement of ions ------ oxidation-reduction process = ___
oxidation-reduction process ------ corrosion = ___
corrosion ------ permanganate titration = ___
permanganate titration ------ electochemical cell = ___
electron transfer ------ oxidation-reduction process = ___
movement of ions ------ corrosion = ___
corrosion ------ electrochemical cell = ___
electron transfer ------ corrosion = ___
movement of ions ------ permanganate titration = ___
oxidation-reduction process ------ electrochemical cell = ___
electron transfer ------ permanganate titration = ___
movement of ions ------ electrochemical cell = ___
electron transfer ------ electrochemical cell = ___

SECOND TASK

Now add up the individual scores, crossing out each KEY IDEA as you go.

KEY IDEAS	INDIVIDUAL SCORES					TOTAL
electrochemical cells						
corrosion						
oxidation-reduction process						
electron transfer						
movement of ions						
permanganate titration						

THIRD TASK

Now write the KEY IDEAS in order of relatedness from highest score to lowest. (If some have the same score put them on the same line.)

_____ _____ _____
_____ _____ _____
_____ _____ _____
_____ _____ _____
_____ _____ _____
_____ _____ _____

FOURTH TASK

Take the sheet of printed labels of KEY IDEAS and stick them LIGHTLY on the CONCEPT MAP (Green Paper) starting with the highest score near the top of the sheet. Leave two or three level lines free at the bottom. Later when you have finished the whole CONCEPT MAP, you can press down the labels firmly.

FIFTH TASK

Now join up the KEY IDEAS and write SENTENCE WORD(s) on each connecting line between the KEY IDEAS. Try to cross link as much as possible.

SIXTH TASK

GO BACK TO THE TOP OF THE PAGE. THE SECOND COLUMN on the map using your sheet of printed labels. TRY and place all these as the most important ones on the higher levels and others on the lower levels. Then try to join all the key ideas up with SENTENCE LINES. (Remember to put SENTENCE WORDS on each line!).

YOU HAVE NOW COMPLETED YOUR MAP

FIGURE 2 Constructing a concept map: Year 11 Oxidation-Reduction revision

the points for each concept. The concepts are then ranked in order and placed on the larger sheet of paper using the labels. The most related concept is placed on the top lines of the map and the less related concept on the lower lines of the map. These key concepts are connected by propositional statements. Now the Second Column concepts are placed on the map, at a position which the students feel (in a quite qualitative manner) is appropriate to the generality of the concept. These concepts are then linked into the first structure by propositional statements.

We have found that once students are familiar with the procedure, a map containing between 15-20 concepts can be constructed within forty minutes without reference to a textbook. However, the procedure has been used as a homework revision task and students encouraged to use their textbooks. In such circumstances students tend to take a longer time to complete the map. An example of a map constructed using this procedure is presented in Figure 1.

EVALUATION OF CONCEPT MAPS

Previous work by Novak (1981) served as a foundation in the development of the present evaluation procedure for concept maps. A major problem faced by the researcher/teacher in evaluating concept maps is the fact that concept maps are idiosyncratic. Because of this particular feature there is no one 'correct' map nor is it possible to have an 'ideal' map. Also, there are additional problems in evaluating concept maps which contain a large number of concepts. These include difficulties in evaluating maps for the presence of hierarchy and determining the extent that the map has a structural sequence of concepts ordered from general to specific. As well we found that the different scoring schemes as devised by Novak (1981) were too simplistic to adequately differentiate development attributes for a concept learning profile.

The evaluation scheme presented in Table 1 attempts to overcome these problems and has the following features:

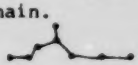
(1) it contains criteria that are easy, and quick to use and are also easily recognisable/identifiable on a concept map. It is pointed out in the scheme, as presented in Table 1, that not all the concepts are scored for hierarchy and as well they are scored on the basis of a teacher/expert predetermined hierarchical structure. The reason for this approach is largely pragmatic. Firstly, the idiosyncratic nature of the concept makes it a very difficult task to envisage/identify the hierarchical level of a large number of concepts - hence the reason for choosing only to score the First Column concepts. Secondly, predetermined hierarchical structure was seen to serve as a base structure. We found that it was not very difficult for teachers to obtain agreement on the ordering of relatedness of a small number of concepts.

(2) it has a scoring system that differentiates between different levels of concept development.

As well, and most importantly, the evaluation scheme incorporates Ausubelian learning principles. The propositions that link concepts are seen as a measure of the degree of differentiation of constituent concepts. Hierarchical differentiation has occurred with respect to the levels of exclusiveness and inclusiveness of concept meanings.

Grouping of concepts on a map is a further way of showing relationships and interrelationships between concepts and can be seen as a measure of integrative reconciliation of meanings. Grouping scores can be effectively used to identify the extent of concept of growth in learning that has occurred.

TABLE 1 Evaluation of a Concept Map

CRITERIA	DEFINITON	SCORING PROCEDURE	PROFILE SCORE
Concept Recognition	Concepts are objects, events, situations or properties of things that are designated by a label or symbol.	Count all concepts that are connected to other concepts by propositions. Score 1 point for each concept.	
Grouping	Groupings are the ways concepts can be linked or joined together. Three types of groupings are: Point grouping: a number of single concepts eminate from one concept. Open grouping: Three or more concepts are linked in a single chain.  Closed grouping: Concepts from a closed system. 	Scoring of groupings Point grouping: 1 point for each concept in the group Open grouping: 2 points for each concept in the group. Closed groupings: 3 points for each concept in the group.	
Hierarchy	Concepts on a map can be represented as a hierarchical structure in which the more general, more inclusive concepts are at the top of the map; the specific and exclusive concepts are at the lower end of the map.	Only First Column concepts are scored for the degree of hierarchy in the map. This is based upon the extent concepts are present in assigned levels. Four points are given to each concept correctly assigned to a level; 2 points for each concept on level removed from an assigned level; no score for concepts that are two levels removed.	
Branching	Branching of concepts refers to the level differentiation among concepts, that is, the extent the more specific concepts are connected to more general concepts.	Score one point for each branching point which has at least two statement lines.	
Proposition	Concepts acquire meaning through the relationship between concepts. The relationships are represented by connecting word(s) phrases written on the line joining any two concepts. Simple Proposition is a simple English word or phrase. Scientific Propositions. This is a phrase or statement that is composed of technical or scientific word(s).	Simple Propositions score one point for each word or phrase; give half a point for repeated use of simple propositions. Scientific Propositions score two points for each proposition. Give one point for repeated use of scientific proposition.	

PRESENTATION AND ANALYSIS OF RESULTS

In most instances, the score of any one map is presented as a total value. We have experimented with the idea of presenting a learning profile, which plots out the scores of the various attributes of the map e.g. hierarchical structure, propositional statements, in a graphical format (see Figure 3). The advantage of this approach is that difference between individuals can be pinpointed to specific weaknesses, and hence provide a means of identifying the need for remedial action.

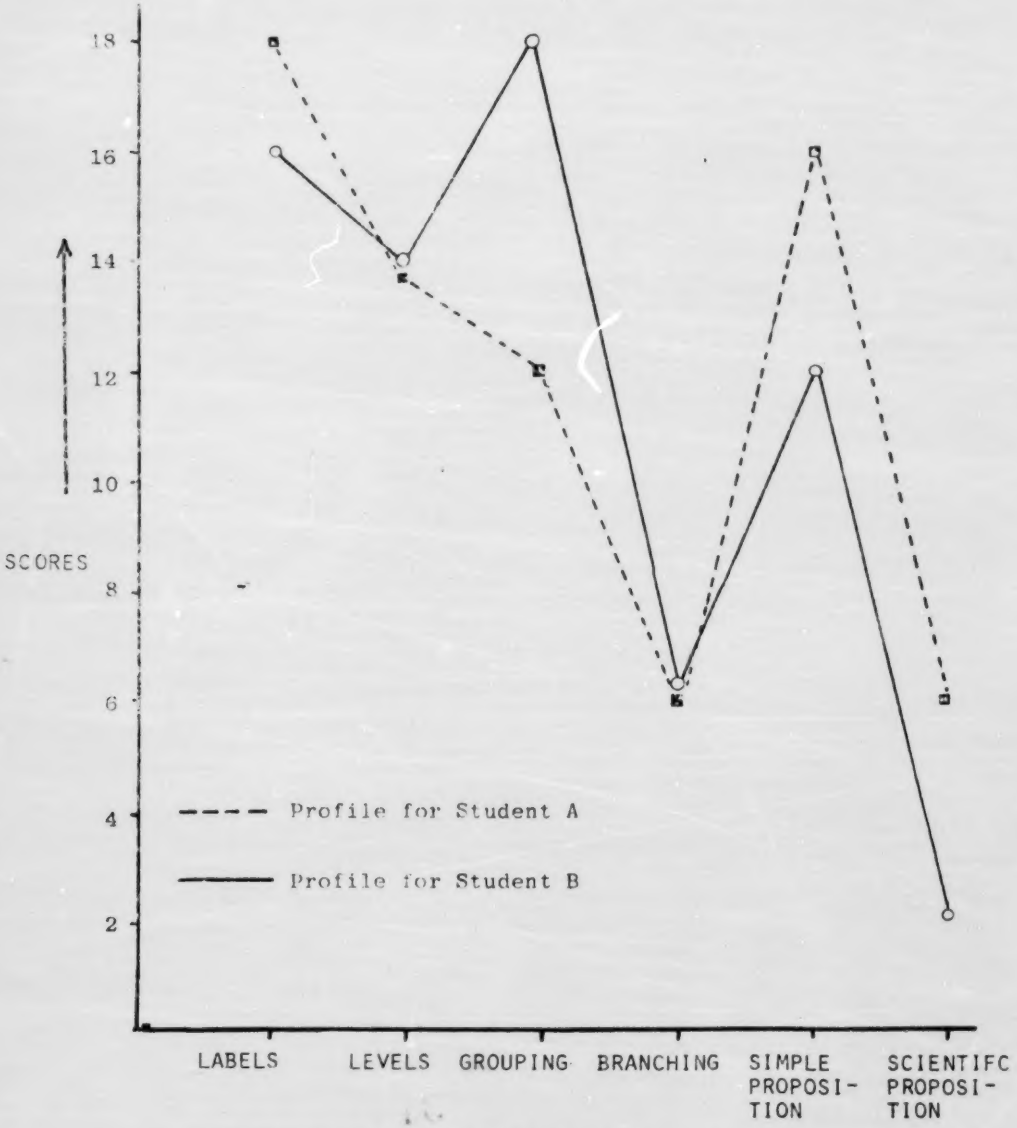


FIGURE 3 Student concept map profile scores

It was interesting to compare the maps of experienced teachers and students on this basis. Although the teachers in general scored at a higher level on all elements of the map, the most significant differences occurred in the quality of propositional statements. Students tended to use simple propositions (simple non technical/scientific words or phrases) to link concepts and use of scientific words of phrases was rare and the use of semi or fully quantitative statements was almost non-existent. This may point to an area of science teaching that needs some attention.

A check on items, which as the number of list words used, can also be productive. In our study, the concept 'equilibrium' was rarely placed on the map, despite the fact that oxidation-reduction is clearly an equilibrium process. The placement of the chapter on equilibrium next to the chapter on redox chemistry in many texts is no accident! The map analysis suggested that whilst many students had achieved satisfactory intra-topic connections, more attention was required on inter-topic connections.

CONCLUSION

The procedures devised for mapping and evaluating maps has been applied to a number of different topic areas both for senior chemistry and for junior science. We believe that this procedure for constructing concept maps is more comprehensive and facilitates student use better than previous procedures. The procedure for evaluating concept maps has also been refined to the point whereby the classroom teacher can readily apply it as part of his/her teaching strategy. The research for this paper further supports concept mapping both as an instructional and evaluative tool.

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CONCEPTUAL CHANGE - FOR PUPILS AND TEACHERS

Roger Osborne

INTRODUCTION

Over recent years an increasing number of researchers have been finding out the views of the world and the meanings for words that children bring with them to science lessons. Driver (1981), Osborne and Wittrock (1982) and Nussbaum and Novick (1982) refer to many of these studies. The outcomes of all this work support the ideas of Ausubel (1968) and Kelly (1969) that children have firmly held conceptions based on their everyday experiences and the common use of language. Children's conceptions are often at variance to scientific conceptions. However, they are sensible and useful from the child's point of view allowing reasonable interpretaion, and successful prediction, of everyday experiences. Various names have been suggested for children's conceptions including 'intuitive knowledge' (Strauss, 1981), 'alternative frameworks' (Driver, 1981) and 'children's science' (Gilbert, Osborne and Fensham, 1982).

Unfortunately children's conceptions are not well known, either to science teachers or curriculum developers, and as a consequence are often ignored in teaching contexts (Tasker, 1981). It is therefore not surprising that children's strongly held ideas frequently remain uninfluenced or are influenced in unanticipated ways, by science teaching (for example see Strauss, 1981; Osborne, 1982a). Indeed Nussbaum and Novick (1982) suggest that we may well come to the view that it is surprising that there are even some children who replace their naive ideas with scientific conceptions.

THE NEED TO CHANGE CHILDREN'S IDEAS

The above findings raise real and important questions about <u>what</u> science should be taught, to <u>whom</u> science should be taught, and what should <u>constitute</u> science (c.f. technology) in the school curriculum. Undoubtedly children enter school interested in finding out about the natural and technolgical worlds in which they live. It can be argued that we, as science educators, want <u>all</u> children as they proceed through the school system to continue

i) to investigate things and explore how and why things behave as they do, and

ii) to develop explanations that are sensible and useful to them.

Also, where possible without jeopardising i) and ii) we want <u>many</u> children,

iii) to recognise that scientists use sensible and useful ways of investigating things (even though these may be different from the child's way), and

iv) to regard at least some scientific explanations as intelligible and plausible, and as potentially useful to society (if not to the child personally).

Also, if possible without jeopardising i) and iv), we want some children,

v) to replace their own intuitive explanations with the explanations of scientists, and

vi) to become committed to the endeavours of science.

If this is accepted then for some children, and for some topics, we need to encourage conceptual change, but not at the expense of the child's own self-confidence, the child's own enthusiasm and curiosity about the world, and the child's own sense of what constitutes a sensible explanation.

RESEARCH ON CONCEPTUAL CHANGE

Driver (1981) and White (1981) both suggest that, while researchers have built up a useful body of knowledge about children's ideas, there remains a real need to investigate the conditions which facilitate conceptual change.

Strauss (1981) suggests that the teaching strategy to be used in any situation should depend on whether or not children have intuitive conceptions about the particular topic to be taught and, if they have, whether or not these conceptions are basically different from, or similar to, the scientific conceptions.

Subsequent discussion in this paper is limited to situations where children have firmly held conceptions which are quite different from those of scientists; situations which require children to give up something that is already known and to replace it with something quite different (Rowell and Dawson, 1982). Hewson (1981a) labels this replacement 'conceptual exchange'. An example would be children replacing pre-Newtonian mechanics conceptions with Newtonian-mechanics (Clement, 1982).

The action-research phase of the Learning in Science Project (see Osborne, Freyberg, Tasker and Stead, 1981) has been centrally concerned with the problem of conceptual change. During 1981 some four researchers and over thirty practising science teachers were involved in a variety of small informal studies. The research has been reported in a series of working papers (see Appendix A) and has led to the production of some teacher guide material (see Appendix B).

This action-research work was largely influenced by the ideas of Hewson (1980). According to Hewson if children are to change their views they must first find their present conceptions unsatisfactory in some way. However dissatisfaction with a present view is not sufficient reason for a child to change viewpoints. Like scientists, children will not reject an idea until they have an alternative idea to put in its place. This new idea needs to be

i) intelligible in that it appears coherent and internally consistent,

ii) plausible in that it is reconcilable with other aspects of the child's view, and

iii) fruitful in that it is preferable to the old viewpoint on the grounds of perceived elegance, parsimony, and/or usefulness.

Hewson (1980) argues that any change in viewpoint is generally a gradual process. Dissatisfaction with an idea comes from a loss of fruitfulness and plausibility. Conversely as a new idea is increasingly perceived as preferable, its status in increased.

One of the problems of teaching science is that the scientists' viewpoint may appear to the child to be less intelligible, plausible and fruitful than the child's present view (Osborne, Bell and Gilbert, 1982).

CHANGING CHILDREN'S IDEAS

The work of the Learning in Science Project together with consideration of the empirical and theoretical work of others (e.g. Karplus, 1981; Strauss, 1981; Driver, 1981; Hewson, 1981a, 1981b; Nussbaum and Novick, 1982; Rowell and Dawson, 1982; Fredette and Lochhead, 1982; Clement, 1982; Osborne and Wittrock, 1982) leads us to propose certain important components in lessons designed to produce conceptual changes.

Teacher Preparation: It is important that the teacher understands the scientists' views, and the children's views, at issue. Also the teacher needs to be able to assess whether or not a certain conceptual change is a reasonable teaching goal with a specific group of pupils. In the Learning in Science Project background notes for teachers set out children's views and scientists' views. Surveys were provided so that the teacher could clarify his or her own view and could establish the prevalence of various views amongst the pupils prior to teaching.

Familiarity with the Context of the Ideas: Pupils need an opportunity to experience the phenomena to be discussed, where this is appropriate (for example, see Karplus, 1981). To illustrate, if electric current in a simple circuit is to be discussed children need the opportunity to observe closely a bulb, battery and wires, and to construct simple circuits, not once, but a number of times.

Clarification of a Child's own View: Tasks need to be provided so that a pupil must clarify his or her own view about the particular phenomenon under discussion. For example, to focus children's attention on the electric current in a simple battery-bulb circuit children can be asked 'Would there be a current in one or both wires? Which way would the current flow in the wire(s)?' Nussbaum and Novick (1981) suggest one needs to create a critical situation (e.g. question or problem) which requires pupils to invoke and clarify their own frameworks. They suggest we need to encourage pupils to verbally and pictorially describe their frameworks. The Learning in Science Project typically used questions on worksheets for this purpose.

Presentation of Own View: Pupils need the opportunity to debate the pros and cons of their existing frameworks with each other (Nussbaum and Novick, 1981) and in this way pupils are encouraged to state their ideas clearly and concisely. This process encourages attention (Osborne and Wittrock, 1982) in that pupils are aroused to defend their own ideas, have a sustained personal interest in the discussion, and concentrate and focus on the important and relevant issues. In the Learning in Science Project we have found it useful for pupils to first discuss ideas in pairs then in larger groups. In this way all children become actively involved.

Appreciation of Other Views: The learning environment in which the pupils' discussion takes place needs to be supportive in that personal ideas are valued as worthwhile contributions to the learning experiences of the class. Our experience has been that where teachers have first been made aware of the likely views of the children in their class, through teacher guide material, they can confidently seek their pupils' views. In doing so they create an environment where children's views can be brought out into the open, discussed and challenged in the light of alternative viewpoints. Where the scientific

view is not represented strongly or clearly, it is sometimes necessary and/or appropriate at this stage for the teacher to introduce the scientific viewpoint as an alternative view. For the scientific view to be considered seriously it needs to be introduced in a way which takes into account the views children currently hold. For example, to introduce the scientists' view of force we first pointed out to pupils that a concept that many of them label force is the physicists concept of momentum (Osborne and Schollum, 1981).

Changing the Status of Different Viewpoints: To produce conceptual change, pupils not only need to appreciate alternative views, but to perceive these as more intelligible, plausible and useful than their present viewpoint. In some situations even in science, this can only be achieved through discussion and reason, e.g. the concept of 'animal' (Bell and Barker, 1982). However in other situations children's different views can lead to pupils designing and executing a critical test of opposing views. For example, opposing views about the direction and magnitude of the electric current in a simple d.c. circuit can be tested (Osborne, 1982b). However such clashes between particular views and evidence must be handled delicately, and pupils need help in reconstructing their own conceptual frameworks. Emphasis in discussion needs to be on qualitative ideas, since it is too easy to retain old ideas hidden beneath a cloak of successfully manipulated formulae (Gunstone and White, 1981; Clement, 1982). For some pupils a scientific idea, while plausible and intelligible, is not considered realistic enough to be adopted as their own; in our research we have accepted this, leaving our own integrity and the child's integrity intact (for example see Osborne and Schollum, 1981).

Elaboration: Even when children have discussed alternative viewpoints, and have encountered clear empirical evidence which supports only one viewpoint, it is so easy for children to accept the point just to cover the most pressing anomalies and to retain their old viewpoint for all other solutions (Rowell and Dawson, 1982). For example, while we have had children accept that the electric current circulates around a simple battery and bulb circuit in the laboratory, some of these children did not change their non-scientific ideas about the flow of current in a torch and other alternative situations (Osborne, Tasker and Schollum, 1981). Our experiences suggest to us that we have to provide many similar examples and situations and ensure that, through discussion and problem solving, the full implications of any new idea is better appreciated by children. There is some evidence to suggest that the retention of ideas is dependent on a multiplicity of linkages being formed among aspects of knowledge in long term memory (Osborne and Wittrock, 1982). The elaboration of ideas also allows for the new ideas to become increasingly intelligible, plausible and fruitful. Often ideas take time to mature. For example we have been surprised by the number of significant and long-term changes in viewpoints made by children after class discussion of post-unit test results (e.g. Osborne, 1981).

CONCLUSION

On the basis of research findings certain lesson components have been proposed as important if conceptual exchange is to be promoted. The proposals are based, in part, on the work of practising teachers in the action-research phase of the Learning in Science Project. More recently other teachers have been introduced to and are using, the material developed by the action-research groups.

One of the problems with action-research involving large numbers of teachers is the problem of controlling the research and producing hard data on pupils'

conceptual changes (Appendix A). Even more difficult to evaluate objectively are the conceptual changes produced in teachers. Nevertheless we believe that there have been significant conceptual changes in these teachers with respect to science content, methods of teaching, and their role as science teachers:

i) Teachers have appreciated teacher resource material about children's views, scientists' views and the differences between them. Teachers with a limited background in science have been able to clarify their views and all teachers have greater confidence to explore children's ideas in class discussion.

ii) Teachers have appreciated the need for pupils to really clarify some basic concepts, e.g. animal, force, dissolving, before proceeding further with the syllabus. They have been impressed by the level and enthusiasm of the pupil discussion, in the contributions of pupils to the design of experiments to test ideas, and the involvement of pupils in rethinking ideas when predictions fail. While there is always some disappointment when certain chidren do not change their ideas, there has been an open acceptance of this.

iii) Despite the formal completion of the Project, 50% of the teachers involved in the action-research in 1981, and over 20 other local teachers who have been introduced to the material more recently, are now systematically finding out children's views, designing further material, and improving what has been produced so far. In this way many teachers have changed their ideas about teachers as classroom researchers. The Learning in Science Project, and other research of this type, will have achieved all that can be reasonably expected if such work by teachers continues and develops.

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APPENDIX A: Learning in Science Project: Reports of the Action Research Groups

LISP Working Paper	Title
29	Toward solutions: The work of the Biology Action Research Group
32	Toward solutions: The work of the Physics Action Research Group
35	Toward solutions: The work of the Chemistry Action Research Group
46	Toward solutions: The work of the Science Activities Research Group

APPENDIX B: Learning in Science Project: Background notes and suggested teaching activities for science teachers

LISP Working Paper	Title
29	Animals, Plants and Living: Notes for Teachers
31	Teaching about Animals, Plants and Living
33	Force, Friction and Gravity: Notes for Teachers
34	Teaching about Force
36	Burning
37	Changes
38	Heating and Cooling
47	Science Activities: The Problem
48	Science Activities: Specific problems, some solutions
49	Science Activities: Wider issues, some considerations

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STUDENT THINKING IN A SECONDARY BIOLOGY CLASSROOM

John Edwards and Perc Marland

INTRODUCTION

In recent years new paradigms for research on teaching have emerged (Doyle, 1977). One of these, the mediating-process paradigm, has focused attention on students' mediating processes, the covert mental processes that are presumed to intervene between teaching processes and student learning outcomes. According to proponents of this paradigm, to understand how teaching works it is necessary to discover how and to what extent teacher behaviours and other classroom events engage mental processes in students that give birth to or impede learning.

The research reported in this paper investigates the mediating processes of secondary students during classroom instruction in Biology using the stimulated recall technique (Clark and Yinger, 1979). The stimulated recall technique provides access to the mental functioning of students during instruction by having students report their in-class thinking in post-lesson interviews. Videotapes of the lessons are replayed in the interview to stimulate recall of student thinking during instruction. The stimulated recall methodology has been used successfully in recent years in process-tracing research to investigate the mental functioning of teachers (Marland, 1979), physicians (Elstein, Shulman and Sprafka, 1978), and counsellors (Kagan, Krathwohl, Goldberg and Campbell, 1967), at work in their respective task environments. These studies stress the value of this technique for 'getting inside the heads' of people.

METHODOLOGY

Sample

Twelve students nominated by their Biology teacher as representing a cross-section of his 28 member grade eleven class in terms of ability, motivational levels, sex and scholastic success had the research questions and procedures explained to them. Preliminary interviews were then conducted, primarily to select four suitable subjects. The major selection criteria were: ability to express ideas clearly, frankness, ability to articulate their thinking, and willingness to participate. The four students chosen covered a range of ability, achievement and motivational levels.

Techniques

Three Biology lessons were videotaped over a period of one week. Two cameras were used to produce a split-screen image with one camera focused on the teacher and the other focused on the four students and those who regularly sat near them.

Lessons were videotaped in the morning and stimulated recall interviews were conducted during the lunch recess and after-school periods on the same day. In this way each researcher could interview both of his students on the day of the lesson. Emphasis in the interviews was on a full and accurate disclosure

of the interactive thoughts of the student with confidentiality and anonymity guaranteed. The stimulated recall interviews were of approximately one hour's duration and were audiotaped. Transcripts were prepared from the audiotaped records for subsequent analysis.

Context

The research was conducted in a moderately large independent secondary school in a provincial city in Queensland. The lessons which provided the data base for this study were not specially arranged but formed part of the on-going program in Biology for the Grade 11 class and were conducted in the laboratory regularly used for Biology classes. As well the teacher was asked not to consciously vary his regular or planned approaches to teaching the lessons. This was done to ensure, as far as possible, that data from the study would reflect naturally-occurring mediating processes for this teacher.

Apart from the presence of two video cameras and two technicians, the classroom set up remained much the same as usual except that seating arrangements were modified to bring one of the four students and her partner closer to a camera.

In most respects the lessons followed a traditional pattern with lesson- and task-structures being defined by the teacher and treatment of the content being achieved mainly through teacher-controlled, student-teacher interactions involving the whole class. Lesson three was different from the first two in that, after the eleventh minute, students were engaged in independent seat work assigned by the teacher. In this phase of the third lesson, the teacher initiated many contacts with individual students or small groups of students. In the main, however, the instructional approach was a 'mass processing' one (Cusick, 1973), with one information presentation channel, that being monopolised by the teacher.

DISCUSSION OF DATA

The stimulated recall interviews provided voluminous data - over three hundred pages in this study. A detailed report on the data is not possible in an article of this length. Consequently, we have limited our discussion to some of the more prominent general features of the students' mental functioning across the three lessons. These general descriptions have been supplemented with more detailed data on strategies for learning and mediating reponses associated with teacher questions.

What Students Think About - Its Relevance to Lesson Content and Goals

Information processed by the four students during classroom instruction showed a remarkable diversity but, typically, was related to three sources: (1) classroom events involving the teacher and students; (2) events and topics discussed with the neighbour(s); (3) the private inner-world of each student, where such factors as moods, feelings, interests, personal experiences, and fantasies, directed student thinking. The interaction, overlap, and relative dominance of these sources for each student during a lesson is a fascinating and complex study.

Many dimensions of this three-fold classification could be explored but discussion here is limited to one, the extent to which student thinking is lesson-relevant, an important question in teaching effectiveness research. A relatively crude index of relevant thinking, based on the percentage of interview segments containing lesson-relevant thinking, indicates that lesson-relevant thinking for any one student in a lesson varied between 25% and 60%.

And these periods of individual attentiveness seldom coincided for even two students, resulting in a complex array of attention patterns.

Some educators would see this as a depressing situation. However our interviews suggest that periods of off-taskness are important, perhaps essential: as a relief from intensive informating processing; as a means of improving the concentration and clarity of on-task periods; and possibly as a means for better linking new knowledge to existing cognitive structures or elaborating and enriching the material of the lesson.

Factors Influencing Students' In-class Thinking

A systematic analysis of the factors influencing students in-class thinking has not yet been made, but some factors stand out and appear to play a dominant role.

A range of factors, personal to each student, seems to act as primary determiners of attention or involvement. These include: mood; mental set; climatic conditions; private personal experiences; general attitude to the subject; and self-image as a Biology student. As well as these factors, audio-visual materials, student responses (especially from those who provide outlandish or provocative answers), neighbours, and other students can help or hinder involvement.

There is also a range of teacher-initiated actions that generally attract student attention. These include: humour; teacher proximity; personally involving students (for example, by asking questions of, or directing, the student or his neighbour); talking loudly; presenting interesting, challenging or relevant work; and showing enthusiasm or being motivating.

The idiosyncratic nature of the sets of stimuli to which each student responded and the overwhelming variety and unpredictability of their mediating responses ruled out any possibility in this study of identifying consistent stimulus - mediating response patterns.

Teacher-initiated actions also caused students to tune out. These include: labouring a point; saying the 'same old stuff' and dealing with material seen as irrelevant or trivial.

MEDIATING PROCESSES

Tuning in, Tuning out, and Monitoring

There are times when students are attending to the teacher, and times when their attention is elsewhere. These states are referred to as being tuned in or tuned out respectively. Shifts in attention were often frequent during a lesson. One student, for example, in one fifteen-minute segment of a lesson reported thirty-two such attention shifts.

Research to identify the stimuli resulting in attention shifts has obvious value for classroom practice. What makes this difficult is that some students seem relatively unaware of, or unable to articulate, what causes them to tune in or tune out. Also some students seem in more direct control of their attending behaviour than others.

Whether tuned in or tuned out students generally monitor other things occurring in the classroom. Monitoring of teacher behaviour while tuned out is a regular feature of student functioning.

Field Detachment. On some occasions students became so engrossed in their own thinking that they were oblivious to other stimuli round them. It was as if they had closed out all other events or detached themselves from the classroom. This seemed to occur when students were engaged in in-depth processing of information. Kagan et al. (1967) have observed this in teachers and refer to it as the 'field detachment phenomenon'.

Selectivity and Student Power. In this study, student information processing was selective rather than adaptive. That is, students made few attempts to influence the direction of the lesson. They generally chose to sample from what the teacher offered though there were a few instances, of adaptive behaviour such as student-initiated questions and comments and solicitations for teacher help with a problem. They also exercised some covert control through independent learning strategies.

This apparent unwillingness or inability of students to play a more dominant role in adapting the lesson to suit their own learning needs is a cause for concern and an area for research. While some students suggested that the reason they did not redirect the lesson was because they felt that other students did not share their needs or interests, it seems that many students feel that the locus of control is external to them.

Deception Strategies. The students in this study used a variety of deception strategies with considerable success. Generally their goals were: to create an impression of being task-oriented and attentive; to ensure a favourable performance-grade exchange; to avoid becoming the target for questions; and to avoid attracting the teacher's attention so that they could pursue a personal line of thinking.

There were relatively few times throughout this study when either researcher could with confidence infer a student's mental functioning from direct observation. We believe that this brings into serious question the validity of research based on observer inference.

Strategies for Learning. A planned outcome of this study was the identification of strategies for learning used by the students for coping with the intellectual tasks of the classroom. The number of strategies identified in the self-report data of the four students varied markedly. One student isolated and explained uses of, over twenty different strategies (see Table 1). Another student could isolate and explain only six.

Differences did exist between the students in ability; in attitude to the teacher, subject and teaching techniques; in self-image as a Biology student; in achievement motivation; and in ability to apply oneself to a task. There were also considerable day-to-day differences for each student in such areas as mood, mental set, and effect of previous lessons or lessons to come. Each of these factors represents a possible part-explanation for the range of strategies possessed or used. Another plausible explanation relates to differences in student's metacognitive ability, that is their ability to think about their own thinking.

It is not possible at this stage to decide whether it is the absence of strategies, or the inability to recognise and articulate them, or a combination of the two, that represents the real picture. However the data gathered in this study suggest that students do differ greatly in the skills they have available in particular situations. This raises the question of the possibility of using focused programs to develop these skills in students. Recent work done using de Bono's CoRT materials (Edwards and Baldauf, 1982) suggests that there is great potential in such an approach.

TABLE 1 : Strategies for Learning used by one Student

- Evaluates answers given by other students
- Formulates answers to questions asked of other students
- Solves academic problems through discussion with neighbour, solicits help of teacher in-class or after-class (if no agreement reached with neighbour), and engages teacher in debate
- Tries to identify goal of teacher's or student's line of questioning
- Distinguishes what he knows from what he doesn't know
- Compares other student's oral answers with his own
- Arranges with neighbour for both to raise hands to attract teacher's attention re problem (academic), discusses problem with teacher
- Cooperates with neighbour to retrieve important information from text (for rapid information retrieval)
- Analyses task to be attempted: defines what is to be found; sets down what is known, what is not known; identifies ways of finding unknown from known
- Monitors teacher's movement round class, predicts time when contact with teacher is likely
- Formulates own problems and questions, discusses these with neighbour
- Negotiates understanding of problems with neighbour
- Chooses location in class (front row) where contacts with teacher can be made frequently
- Asks questions of teacher on areas of interest in lesson or related to lesson
- Uses logical approach in problem solving
- Remains alert for teacher cues about what is important, examinable
- Attends closely when teacher outlines content of future lessons, prepares for these lessons by previewing new material
- Preserves best answer only (uses for revision), discards less satisfactory ones
- Relates new material to old, to see how it fits together
- Divides classroom task up between self and neighbour for quicker coverage of work
- '(I) set up a debate with myself or someone else to try and find out both sides of an argument and if I'm not quite satisfied then I have a go at the teacher and try and get an argument going with him, to get him to explain his side of the argument'

Mediating Responses to Teacher Questions

Table 2 lists the complete range of mediating processes within one particular category - mediating responses to teacher questions. The list illustrates the richness and complexity of mediating processes, with nine categories being required to subsume the sixty- eight mediating responses.

Implications for teaching practice abound in the data and it is tempting to pursue these. However, until a more detailed study has been completed we prefer to leave this as illuminative data. At the same time, some general research implications have emerged:

1 The diversity of mediating responses in Table 2 leads us to suspect that learning outcomes would be just as diverse as well as varying quite considerably in quantity and quality. Such diversity in outcomes poses a real challenge so far as measurement is concerned and offers one possible reason why process-product research (in which product measures have typically focused on a narrow set of intended outcomes and neglected incidental or unintended outcomes) has so often yielded equivocal results.

2 The data confirm the centrality of mediating processes in determining what is learned, when and how it is learned, or if it is learned at all.

3 This line of research points up the rather limited usefulness of proxy variables (e.g., academic engaged time). It suggests that proxy variables, as measures of information processing variables, are likely to be gross, inaccurate and misleading.

4 Clinical studies of the links between teaching, students' mediating processes and learning outcomes offer a means of refining blunt instructional techniques.

Role of the Neighbour in Student Information Processing

One aspect of student information processing which stood out in this study was the major role played by the neighbour, even in a context in which group work was neither required nor encouraged. It was plain that there was considerable interaction between each of the four students and his or her neighbour. This interaction served a variety of purposes, from assisting learning to 'escaping' from the classroom.

One student used an impressive array of cooperative learning strategies with the neighbour. For example, they divided tasks to allow more rapid progress, shared findings, jointly put up their hands to coerce teacher attention, negotiated understandings, debated problems, and formulated alternative hypotheses.

Another reported mood-convergence with the neighbour. Most of their cooperative effort in the first two lessons was directed towards 'having fun', joking, talking about non-lesson-related issues, distracting each other and distracting others. However in the third lesson they regularly challenged and helped each other with lesson-related activities.

At present much of this productive, cooperative learning is done in spite of the teacher, suggesting that the neighbour may be a greatly undervalued educational resource in the classroom. This invites research into strategies such as introducing regular periods of perception sharing and negotiating understanding with the neighbour throughout a lesson. Novak used such a technique when he lectured at CONASTA 1980 with great effect, and it may be that public speakers and lecturers should consider the technique.

TABLE 2 Mediating Responses to Teacher Questions

(Code: TQ-teacher question; T-teacher; Q-question; N-neighbour; S-student)

TYPE OF MEDIATING RESPONSE

Academic (Student processes the questions and answers)

Individual
- Goes off at a tangent (relevant or irrelevant)
- Judges TQ as unimportant, formulates replacement Q and reflects on own Q
- Evaluates T's answer to TQ, disagrees with it, seeks proof to enable him 'to beat the T'
- Formulates answer (sometimes process is protracted)
- Formulates answer, compares own with other public answers
- Offers answer (S is confident she's 'right')
- Formulates answer to share with neighbour and exclude T
- Restricts own questioning because of fear of being probed (even though he feels probing is productive)
- Recalls source (text) for obtaining answer
- Formulates answer to store in case T asks him to respond
- Tries to identify point of T questioning
- Assesses TQ as elementary, so switches off
- Awaits and monitors response, then judges response
- Formulates answer and keeps it to himself
- Formulates answer to share with class/teacher
- Restricts formulation of answer to own fund of knowledge (won't research)
- Formulates answers casually (without concern for correctness)
- Formulates answer, evaluates own answer, raises hand (if good answer) / awaits response from another (if poor answer)
- Formulates answer, discusses answer with neighbour, seeks help from T or other S (if no agreement on suitability of answer)
- Formulates answer, compares with given answer, stores away better answer or part (when given answer is superior)
- Monitors answer from another, evaluates answer
- Tries to define purpose of specific TQ
- Offers a response in line with perceived T expectations
- Extends perceived T-expected response with her own preferred answer
- Formulates answer, feels confident if answer is believed to be good.

Cooperative
- Discusses TQ with N
- Perceives Q as challenging and designs elaborate answer with N

Attentive (Gets student on task)
- Gets S back on task when whole class is asked Q
- Gets S back on task when N is asked Q by T
- Gets S back on task when S is asked Q

Attributive (Student ascribes motives, intents, goals etc. to teacher and other students)

Perceives questioning as
- T punishment of S
- attention-producing
- T on 'hobby-horse'

- T 'labouring the point'
- T 'trying to get them thinking'
- T 'picking on, having a go at' S
- T desisting unacceptable S behaviour
- T retribution for S's previous anti-social behaviour
- T genuinely interested in S
- T directing Q's to 'smart' side of class
- T directing Q's to poorer students to lead them to the right answer rather than asking those who might know

Deceptive (Student sets out to mislead teacher, protects himself and other students)

- Considers he is unable to answer Q, improvises answer (something clever)
- Answers TQ with an 'intelligent' Q (to put T off)
- Just listens enough to get the gist of the Q so he can repeat TQ or fudge an answer
- Replies on behalf of N to TQ to reduce likelihood of being the next S to be 'grilled' (asked Q's)
- Acts intelligently when he does not know the Q
- Responds with own Q on related topic he is familiar with

Emotional (Student expresses feelings about question or teacher)

- Feels reassured of his ability to work ahead of the class
- Feels relief at being able to hear TQ
- Makes S feel on the spot, nervous and muddled and embarrassed (probing Q's)
- Feels relief when T redirects away from her
- Dislikes complicated, divergent Q - likes straightforward Q
- Enjoys T questioning which leads her to her own better answer (does not happen often)
- Feels indifferent

Manipulative (Student tries to create favourable impressions, cast himself in a particular light or contrive circumstances to derive personal benefit)

Cooperative

- Replies to TQ on behalf of N to get N off the hook

Competitive

- Considers T has asked someone 'dumb' who can't answer, so S answers to impress
- Interjects comments in T-N question-answer discussion so as to 'sound brilliant'
- Considers that if everyone puts up hand and he has good answer he should wait and inject it near the end

Non-Cooperative (Student resists or ignores teacher questions)

- 'Switches off'
- Decides not to put hand up to offer an answer
- Calls out answer to upset T
- Refuses to think about TQ (just sits there and lets others answer)
- Gives smart answer to N for a laugh
- Deliberately sets up an argument with T (S is in good mood)
- Joins with N in attempt to ridicule other responses (they do not formulate own responses)
- Makes a flippant answer to TQ
- Talks to N while T asks Q
- Responds with bizarre answer (not intended for T), converts into an acceptable answer for T (if T asks about first response)

VALIDITY OF THE DATA

This is an obviously complex issue. The extent to which human behaviour is consciously purposive is arguable to begin with. Even accepting this, the ability to recall accurately and to articulate clearly, the effect of time lapse, the relation of post hoc justifications to situational realities, and the possible effects of willingness to 'please' interviewers and self-fulfilling prophecies, remind one to proceed with caution. However, after careful reading of the literature (for example, Shulman and Elstein, 1975) we were convinced that stimulated recall offered us the best route to accurate data.

When questioned about the validity of the data the students commented:

- "Oh well I'm not telling you the things I'd like to hear. I'm trying to kind of remember what I was thinking at the time ... but sometimes the actions are mixed up ... 'cause sometimes they all look the same ... I can't think of what you'd like me to think of".

- "The camera wasn't forgotten all the time, and we weren't exactly natural, but it was sort of more on the way to what a normal classroom would be."

- "If you don't know what kind of things you're thinking about you're going to be put in an embarrassing spot, so you're sort of keeping track of what's happening out the e and what you're thinking, and sort of, during the day yo sort of put all those thoughts into order, it's just sort of the natural thing if you know you're expecting to have an interview."

- "Well I don't think you think about thinking normally. You only think about thinking when you're trying to. So it would be almost impossible to do it any other way. So I suppose it would be about as accurate as at least students could get it. Because to just think naturally and remember it, no one does that I don't think, or no one that I know ... I think that what I'm certainly giving you is as close as you're going to get."

- "I'd say about 95% of the thoughts that I actually recalled I told ... and they were completely accurate as far as I could actually try and describe them."

RETROSPECT AND PROSPECT

This paper reports the very early phase of what is to be an extended piece of research. The treatment of data has been mostly descriptive rather than interpretive. The temptation to generalise from limited data has been resisted, with difficulty at times. The data reinforce the great complexity of the teaching/learning process. What shines through strongly from these four students is the idiosyncratic nature of student learning. While many teachers accept this as 'the situation', few can show how this realisation manifests itself in the teaching styles they commonly use.

In our view the stimulated recall methodology offers a valuable way of investigating student mediating processes during classroom instruction. The yield from such research, especially for understanding how teaching affects learning and thereby improving teaching, looks promising. What lies ahead is much more detailed analysis and conceptualisation.

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PATTERNS OF REASONING: PROBABILITY

Kenneth Tobin

INTRODUCTION

The study of formal reasoning ability has become increasingly important as educators endeavour to understand learning in adolescence. Recent studies have tended to focus on five reasoning modes: proportional reasoning; controlling variables; probalistic reasoning; correlational reasoning; and combinatorial reasoning. In science education, investigators have tended to research four of these: proportional reasoning; combinatorial reasoning; controlling variables; and correlational reasoning (e.g. Lawson, Adi, and Karplus, 1979; Lawson, 1979; Linn and Pulos, 1979). However, probabilistic reasoning has numerous applications in science. For example, concepts related to the gas laws, Mendelian genetics, and atomic structure require some understanding of probability and many activities advocated for middle school grade levels also utilise probabilistic concepts. For example, if in an investigation of the effects of exercise on pulse rate, exercise is defined and manipulated in the same way for a number of subjects, then mean values can be used in hypothesis testing. An understanding of the basis for using mean values necessitates an understanding of the probabilistic nature of human behaviour. Thus, there are two aspects of probability involved in science: computation of the odds of success in situations such as those encountered in genetics; and understanding the probabilistic nature of events when planning investigations. Little research has been conducted on the relationship between an ability to estimate the odds in problem situations and an ability to explain observations in terms of probabilistic phenomena. However, a probabilistic view of observed phenomena might develop from activities requiring pupils to estimate the odds (see Fischbein, 1975, p. 93).

Extensive research on the development of probabilistic reasoning is reported by Inhelder and Piaget (1958, 1975), and Fischbein (1975). However, the generalisability of the reasoning patterns identified and described has not been demonstrated and replicated in studies that incorporate large samples. The majority of these studies has been characterised by relatively small samples and the assessment of few reasoning modes. A recent exception was a study report by Tobin, Capie and Newton (1981), which was based on data from more than 2,000 subjects and five reasoning modes.

In a study of probabilistic reasoning Tobin et al. (1981) reported three common response patterns for samples of subjects in college, secondary and middle school grade levels. The research reported in this paper extends the work of Tobin et al. (1981) with a sample of upper primary school students from Australian schools. The purpose of the study was to identify stable incorrect reasoning patterns that might present a barrier to learning. If frequently occurring reasoning patterns exist, then curriculum materials might be designed to highlight reasoning deficiencies. Teachers can then use questions and explanations to probe for misconceptions and provide examples of alternative reasoning strategies. Two research questions provided a focus for the study:

1. Are patterns evident in responses to problems requiring the application of probabilistic reasoning?

2. Are patterns in probabilistic reasoning related to patterns in controlling variables?

PROCEDURES

Data from 908 subjects in upper primary years 6 and 7 were collected using the Test of Logical Thinking (TOLT) (Tobin and Capie, 1981). The psychometric characteristics and item format made the TOLT particularly well suited to this investigation. Tobin and Capie reported internal consistency reliability coefficients for the TOLT to be approximately 0.8. Evidence was also reported of high correlations between performance on the TOLT and performance on five standard Piagetian interviews. Other validity data argue for construct and criterion-related validity of the TOLT.

Subjects are presented with ten items, two items for each of five reasoning modes. Two problems in the TOLT involve probabilistic reasoning. Each of these items requires subjects to calculate the odds of selecting one object on the first occasion from a number of objects. The items are presented in Figures 1 and 2. In each item the subject is required to choose a correct answer from five alternatives, and then select a justification for the choice from five that are provided. Thus, twenty-five possible combinations exist for each item.

A gardener bought a package containing 3 squash seeds and 3 bean seeds. If just one seed is selected from the package what are the chances that it is a bean seed?

a. 1 out of 2
b. 1 out of 3
c. 1 out of 4
d. 1 out of 6
e. 4 out of 6

Reasons

1. Four selections are needed because the three squash seeds could have been chosen in a row.

2. There are six seeds from which one bean seed must be chosen.

3. One bean seed needs to be selected from a total of three.

4. One half of the seeds are bean seeds.

5. In addition to a bean seed, three squash seeds could be selected from a total of six.

FIGURE 1. A test item requiring probabilistic reasoning: The Vegetable Seeds

To determine whether answers and reasons were randomly selected, a 5 x 5 contingency table was used to crosstabulate answers and justifications for each probabilistic reasoning item. The strength of the relationship between answer and reason was estimated with a chi-squared analysis.

A gardener bought a package of 21 mixed seeds. The package contents listed: 3 short red flowers
4 short yellow flowers
5 short orange flowers
4 tall red flowers
2 tall yellow flowers
3 tall orange flowers

If just one seed is planted, what are the chances that the plant that grows will have red flowers?

a. 1 out of 2
b. 1 out of 3
c. 1 out of 7
d. 1 out of 21
e. other

Reason

1. One seed has to be chosen from among those that grow red, yellow or orange flowers.

2. 1/4 of the short and 4/9 of the talls are red.

3. It does not matter whether a tall or a short one is picked. One red seed needs to be picked from a total of seven red seeds.

4. One red seed must be selected from a total of 21 seeds.

5. Seven of the twenty-one seeds will produce red flowers.

FIGURE 2. A test item requiring probabilistic reasoning: The Flower Seeds

The TOLT contains two problems dealing with pendula of different weights and lengths. One question requires the subject to vary weight, and the other requires weight to be held constant. Subjects choose one of five sets of pendula to use in an investigation. They then choose a justification for their choice from among five alternatives. Capie, Newton and Tobin (1981) reported that three common approaches were used by individuals confronted with situations where variables should be controlled. They are: correct response and correct reason; testing all possibilities without regard for controlling variables; and testing extreme examples (such as longest and shortest) without regard for controlling variables. The common reasoning patterns identified in the Capie et al. study were used as a basis for categorising pupil responses to the pendulum's weight item in this study (Figure 3).

A 3 x 3 contingency table was formed for the subjects selecting the most common response pattern for a probability item and the controlling variables problem. The strength of the relationship was estimated using a chi-squared analysis. A-priori hypotheses for between cell differences were tested using the Dunn-Bonferroni procedure (Dunn, 1961). The analysis was conducted separately for each of the problems requiring probabilistic reasoning.

In order to achieve an estimation of the internal consistency or reliability of the twenty item aggregate, Cronbach's Alpha statistic was calculated. It yielded a coefficient of 0.8, which indicates a reliable instrument for the measurement of teachers' attitudes to Science. This compares favourably with the 0.69 and 0.72 respectively for Spooner and Simpson's pre and post tests (1979, 418).

A factor analysis was carried out on the attitude scale data. Five, four, three and two factor analyses were attempted, and in each case, two factors had eigen values greater than 1.00. The two factor solution produced eigen values of 4.36 and 1.39 respectively.

The first factor (Factor 1) accounted for 76% of the variance and involved major contributions from eleven items (2, 3, 5, 9, 12, 13, 15, 16, 18, 19, 20), whilst the second factor (Factor 2) accounted for 24% of the variance and was characterised by five items (7, 8, 10, 11, 14). The major items which contributed to Factor 1 were:

Item 2 Primary science teaching should (not) be based on a text book approach.

Item 3 Primary students should have had many 'hand-on' experiences in science such as field trips, experiments, etc.

Item 5 Multiple references are more desirable than a single text in teaching science.

Item 9 Student understanding of the processes of science, such as measuring, clarifying, and observing, is as important as knowing the facts and concepts of science.

Item 12 The science teacher should be a good guide or facilitator of learning - not a teller.

Item 13 Student interaction and exchange of science ideas are an important part of learning.

Item 15 Field trips should be an important part of primary science teaching.

Item 16 Developing favourable student attitudes towards science is an important part of science instruction.

Item 18 Students should (not) know exactly what results they are going to get before doing science experiments.

Item 19 Open-ended teacher-directed questions are very appropriate for science teaching.

Item 20 Primary science should correlate well with other subject areas such as reading, maths, art, etc.

Factor 1 would appear to be an enquiry/involvement-orientated open approach to curriculum, or a concurrence with the aims of the school Science course, and so will be referred to as the 'Concurrence With the Course Objectives Factor.'

The five items which characterised Factor 2 were:

Item 7 I enjoy teaching primary science.

Item 8 My undergraduate college training in science has been of much value in teaching primary science.

Item 10 My background is (not) inadequate for effective primary science teaching.

Item 11 I feel comfortable using living organisms in the classroom.

Item 14 I feel comfortable using science equipment.

Thus factor 2 would appear to relate to teachers' backgrounds and confidence in teaching science and will be named the 'Teacher Background/Confidence Factor'.

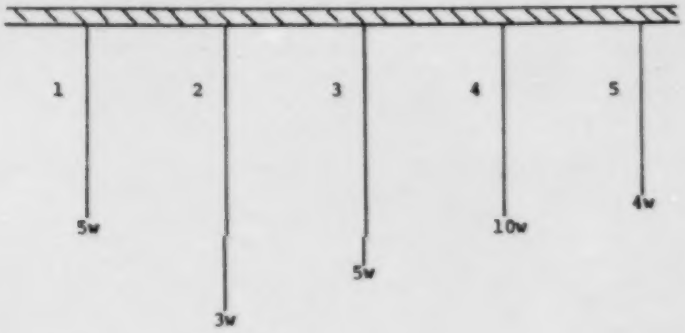
Factors 1 and 2 yielded alpha values of 0.82 and 0.70 respectively, thus confirming the reliability of the scales. In isolating the Concurrence with the Course Objectives Factor, as well as the Teacher Background/Confidence Factor in a teacher's attitude to Science, the attitude inventory supports the arguments which had been proposed by the Primary Science Curriculum Committee in support of the association of a comprehensive in-service teacher education programme with the introduction of the Science course.

The attitude scores were collapsed into three groups which were as close to being numerically equal as possible. The bottom 31.6% formed the low attitude group, the next 34.2% comprised the middle group, and the upper 33.2% made the high attitude group. These collapsed scales were cross-tabulated with a range of other variables.

The Chi square statistics were calculated. They indicated a significant negative relationship between the collapsed attitude scores and teachers' experience ($\chi^2 = 11.90$, df = 4, $p < 0.02$). Positive relationships were found between the collapsed attitude scores and Science studies in Year 12 of schooling ($\chi^2 = 7.84$, df = 4, $0.1 > p > 0.05$, NS), the amount of teacher in-service attendance ($\chi^2 = 9.82$, df = 4, $p < 0.05$), and the teachers' familiarity with, and use of, the Victorian Education Department's science courses ($\chi^2 = 18.87$, df = 8. $p < 0.02$).

CONCLUSION

This study is preliminary in nature, and the instrument will require some modification to reduce its length and to further increase the reliability of the attitude scale. None-the-less, in addition to replicating some important aspects of previous studies, and introducing a measurement of primary school teachers' science related attitudes, it does provide valuable data prior to the introduction of the new course guides. When used in conjunction with the findings of a similar survey which is to be conducted in 1983, these data will help to assess the impact of the introductory phase of the course in Victorian Schools.



Suppose you wanted to do an experiment to find out if changing the weight on the end of the string changed the amount of time the pendulum takes to swing back and forth. Which pendulums would you use for the experiment?

a. 1 and 4
b. 2 and 4
c. 1 and 3
d. 2 and 5
e. all

Reason

1. The heaviest weight should be compared to the lightest weight.

2. All pendulums need to be tested against one another.

3. As the number of washers is increased the pendulum should be shortened.

4. The number of washers should be different but the pendulums should be the same length.

5. The number of washers should be the same but the pendulums should be different lengths.

FIGURE 3. A test item requiring control of variables: The Pendulum's Weight

RESULTS

The results for each research question are presented separately in the sections below.

Research Question 1

For each probability item a significant chi-squared value indicated a strong relationship between the choice of an answer and the choice of a reason for selecting the answer. The respective chi-squared values for the vegetable seeds and the flower seeds items were 667.5 and 342.2 ($df = 4$, $p < 0.0001$).

The results suggest that the answers selected for the probability items are related to the reasons selected for the answers being correct. Three reasoning patterns were evident for each probability item. The presence of these reasoning modes is consistent with findings reported by Tobin et al. (1981) for American pupils at middle school, secondary school, and college levels.

The most common incorrect responses on the flower seeds item were 1/21 and 1/7. As was the case with the vegetable seeds item two reasons were frequently volunteered: one seed needs to be selected from a total of twenty one seeds; and one red seed needs to be selected from a total of seven red beans. The correct response pattern also occurred more frequently than would be expected by chance alone, however, the flower seeds item was more difficult than the vegetable seeds item. This result was also consistent with the results of prior research.

A sample of 221 pupils selected one of the three common response patterns for each of the probability items. The crosstabulated results included in Table 1 indicate that the reasoning pattern used to solve the vegetable seeds item was related to the reasoning pattern used to solve the flower seeds item. Statistically significant differences were obtained for seven of the nine a-priori contrasts conducted in this analysis. In each case the differences in cell proportions supported the research hypotheses.

TABLE 1 Frequency Distribution for Common Response Patterns on Items Requiring Probabilistic Reasoning (n=221)

Vegetable Seeds	Flower Seeds		
	Correct Response	Probability based on total set	Probability based on favourable set
Correct Response	23	5	7
Probability based on total set	5	100	33
Probability based on favourable set	2	21	25

$\chi^2 = 112.62$ df = 4 $p < 0.0001$

Significant contrasts ($p < 0.05$)

$p_{11} - p_{12}$

$p_{11} - p_{13}$

$p_{22} - p_{21}$

$p_{22} - p_{23}$

$p_{23} - p_{21}$

$p_{33} - p_{13}$

$p_{23} - p_{13}$

Approximately 25 percent of the pupils selected one of the three common response patterns for each probability item. This percentage is regarded as high in view of the 25 response options available for each problem. The follow-up tests indicated that pupils tended to use the same reasoning pattern in each probability problem. In fact the results contained in Table 1 show that 67 percent of the pupils who selected a common response pattern for each item used the same reasoning pattern in each case. These results provide evidence of the stability of the reasoning patterns used to solve problems that require probabilistic reasoning. An interesting result is that 44 percent of the sample that selected an answer based on the number of elements in the favourable selection set for the vegetable seeds item provided a response based on the number of elements in the total set in the flower seeds item. This result is consistent with an intepretation that some pupils use a less complex form of reasoning when the complexity of the problem increases.

TABLE 2 Crosstabulated Response Patterns for Controlling Variables and Probabilistic Reasoning : Flower Seeds (n=232)

Flower Seeds	Controlling Variables		
	Correct Response	Use of Extreme Cases	Use of Materials
Correct Response	22	6	4
Probability based on total set	29	52	39
Probability based on favourable set	22	35	23

$\chi^2 = 24.34$ 4 df $p < 0.0001$

Significant contrasts ($p < 0.05$)

$p_{11} - p_{12}$

$p_{11} - p_{13}$

$p_{22} - p_{21}$

Research Question 2

A non-significant chi-squared value suggested that the response patterns on the controlling variables item were not related to the response patterns on the vegetable seeds item ($\chi^2 = 4.71$, $p > 0.3$). The crosstabulation of response patterns for controlling variables and the flower seeds item is contained in Table 2. The chi-squared analysis indicated a significant relationship between the response patterns for controlling variables and the flower seeds ($\chi^2 = 24.34$, $p < 0.0001$). Three between cell contrasts were statistically significant ($p < 0.05$).

1 Of the pupils who selected the correct response pattern, the number able to control variables was greater than the number of pupils who attempted to solve problems by comparing extreme cases.

2 Of the pupils who selected the correct response pattern, the number able to control variables was greater than the number of pupils who attempted to solve problems by comparing all cases.

3 Of the pupils who selected a response pattern based on the total number of elements, the number who used a comparison of extreme cases was greater than the number who controlled variables to solve the problem.

The results suggest that an ability to control variables was not required in the vegetable seeds item. This result might have been anticipated since seed type and the number of seeds were the only variables in the problem. As a consequence, the most important cognitive operation required to solve the problem was to form the ratio of the number of elements in the favourable selection set to the total number of elements.

The flower seeds item was more complex in that three variables are incorporated in the problem. The variables are: plant height; plant colour; and the number of plants. In this case pupils who had demonstrated an ability to control variables tended to correctly solve the flower seeds item more often than pupils who utilized either of the other common reasoning patterns evident in problems where variables need to be controlled. An interesting result in this analysis was that pupils who tended to compare extreme cases in the controlling variables problem selected a probability based on the total number of cases more often than they selected the correct response. These pupils tended to focus on extreme cases in constructing the ratio to represent the probability. At one extreme was the number of seeds to be selected (1) and at the other, the total number of seeds (21). The results of these analyses support the hypothesis that control of variables is needed to calculate a probability when the number of variables incorporated into a problem is increased.

GENERAL DISCUSSION

There are several possible implications of this research for instruction. In view of research reported by Fischbein (1975) suggesting that probabilistic reasoning may be promoted through instruction, the results can provide teachers with guidelines to develop reasoning ability. When problems need to be solved requiring probabilistic reasoning, difficulties similar to those described above are likely to be encountered. Clearly, in many middle school classes both patterns of incorrect reasoning will exist along with an ability to correctly calculate the probability. A teacher should attempt to accommodate learners of each type in some way. Pre-instruction may assist to highlight the shortcomings of the above types of reasoning ability and enhance understanding of concepts that are probabilistic in nature. Because of the stability of the incorrect reasoning patterns, pupils should be shown shortcomings in their approach to solving problems unless they persist with erroneous modes of reasoning.

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TEACHER LANGUAGE COMPLEXITY AND PUPIL TASK INVOLVEMENT

Daphne M. Buckley

The Science Classroom Management Project, of which this study is a part, set out to identify teacher behaviours which provide opportunities for increased pupil learning and to evolve ways of demonstrating effective behaviours to beginning teachers.

While there do not appear to be generic skills appropriate to all teaching-learning settings, the importance of language to all learning is unquestioned.

Communication patterns in school classrooms are dominated by teacher talk and the quality of the communication and its effect on the learning of pupils can be attributed to a variety of verbal and non-verbal factors. This investigation looks at the effect on pupil involvement (as an indicator of learning) of two aspects of teacher talk, the use of subject specific (technical) terms in the discipline area and the use of 'secondary classroom' (non-colloquial), language.

Vygotsky (1962) proposed that word meanings already in a person's language govern the category of objects and events a person can manipulate in his thinking. As vocabulary increases, so does the ability to form and manipulate concepts. Disciplines such as science with its wide register of specialist terminology pose particular problems for the young learner, unless understanding and assimilation of the technical terms introduced are aided by explanation (Barnes, 1971).

Language forms not specific to a school subject which make up the language of the secondary classroom and which pupils would not normally hear or use outside the classroom or school, also have been viewed by many researchers as a major potential barrier to learning (Barnes, 1971; Stubbs, 1976; Gardner, 1972; Richards, 1978). A search of the literature did not reveal research which has measured the effect of the use of this register of the language of secondary classrooms.

METHOD

The teacher use of subject-specific terms, with and without accompanying explanation, and secondary classroom language were investigated in natural classroom settings against a measure of pupil involvement in the set tasks of the lesson. Pupil task involvement is taken frequently as a valid indicator of pupil learning (Carroll, 1963; Bloom 1973, 1976; Harnischfeger & Wiley, 1975; Romberg, 1976); its measurement is described in an earlier report of the Project (Butler, Beasley, Buckley and Endean, 1980).

This study was preceded by a pilot study (Buckley & Barnes, 1981) which analysed tapes from four video-tapings of each of sixteen science classrooms (Years 8-10) in six Brisbane high schools in 1979. The present investigation analysed video-tapes obtained from eight teachers of the pilot study who were still available and teaching Year 8 classes in 1981. For each class of the

latter sample, three lessons were video-taped in the first two-three weeks of the school year and a fourth after a six-eight weeks interval.
Video cameras and radio microphones were placed as inconspiciously as possible and the technician was at the rear of the classroom. Subjective judgement of the effect of videotaping on pupil behaviours was that pupils showed little response to the alien presence after the first 10-15 minutes of the first videotaped lesson and measurements of pupil task involvement bear out this judgement. At the time of taping, the teachers were unaware of the focus of the study apart from the degree of pupil task involvement and it was considered that alteration of speech patterns from normal would be minimal.

For the general purposes of the Project, the video-taped lessons were coded into distinct segments based on teacher structuring of the lessons. For the language analysis, segments identified as 'exposition, with or without props' were chosen. 'Exposition' segments are defined as those which present new material which aims to develop the cognitive or psychomotor skills of pupils by means of teacher talk. Exposition segments are those most commonly used by teachers in the Project, and afford comparability across teachers as well as providing the most concentrated flow of verbal communication.

Subject specific terms are defined as terms representing discipline-based concepts such as 'electron', 'density', 'one-celled', 'control-experimental'. Each first utterance of a technical term was recorded on a data sheet. In addition a record was made of such terms which were presented with verbal and/or non-verbal explanation, such as an analogy, a previously encountered member of the set, visual aid and so on.

Secondary classroom language is not a clearly definable register. In the pilot study, coders recorded all categories of utterances of secondary-classroom terms. Examples of secondary classroom language terms are 'constitutes', 'trend', 'function', 'alternatively', 'frequently', 'in general', and passive verbs such as 'is given off', 'is applied'. A list of all the terms recorded from all the teacher tapes was compiled and edited. Terms were included on the basis of constituting difficulty of comprehension for pupils on the judgement of the coders and the researchers (all of whom were past or current science teachers). Reference was also made to current pupil texts and the tested word lists of Gardner (1972). The edited list was then used as reference. Terms were scored on their first occurrences.

In this study the secondary language reference list was compiled on the judgement of four coders and the researcher and then further edited on the basis of two word lists, a list of logical connectives (Gardner, 1977) and a list of words tested and found 90% comprehensible at Year 8 level (Gardner, 1972). In other respects the recording was similar to that of the pilot study. The results of the term counts were expressed as the frequencies of first utterance per thousand seconds.
Each tape was coded by at least two independent coders.

DISCUSSION OF RESULTS

Subject-specific terms

As shown in Table 1, the significant negative correlation (-0.57) between the frequency of use of the total subject-specific terms and the pupil task involvement measure is similar to the result from the pilot study (-0.50) and supports the hypothesis that the use of such terms can have a detrimental effect of pupil learning.

TABLE 1 - Correlations of Counts with Pupil Task Involvement

	This Study	Pilot Study
Subject-specific terms Frequency/1000 secs.	-0.57	-0.50
Subject-specific terms - explained Frequency/1000 secs	+0.45	not available
Secondary classroom language terms Frequency/1000 secs	+0.44	-0.11

The sample for this study was drawn exclusively from Year 8 classes - pupils in the first weeks of secondary schooling. They were unlikely to have been exposed to science technical terms to any extent prior to the taped lessons. For these reasons it was determined that there could be less uncertainty about the novelty of their classroom language experiences than could be claimed for the pilot study example, a factor which could explain the quite different and higher correlation. Regression analysis of the study indicated that 32% of the total variance measured in the investigation was attributable to the use of subject-specific terms (explained + unexplained).

Explained Subject-specific terms

The positive correlation of explained terms to pupil task involvement (+0.45) provides support for the hypothesis that, when explained, subject specific terms can enhance pupil learning. In the pilot study the measurement of this variable was recorded using a different basis so the comparison of results was not appropriate.

Secondary classroom language

The statistical non-significance of the negative correlation (-0.11) between teacher use of this register and pupil task involvement in the pilot study and then the reversal (+0.44) of the correlation in this study are contrary to the opinions of writers cited earlier. Some factors which probably contribute to the results and which have not been adequately, if at all, taken into account are:-

> The major difficulty of defining the register. In this study, attempts to decrease the subjectivity of decisions were based on lists compiled and tested for reading comprehension. A more appropriate basis for inclusion of terms would be the later testing of the class for comprenension of the terms used by the teacher during the lesson.

Pupils' abilities to cope with language are at least in part derived from their social background. This factor could have affected the results of the two studies, but could be reduced in effect if the testing suggested above were adopted.

A teacher's ability to communicate verbally is affected by the sentence patterns used as well as the choice of terms, a factor not considered in the study.

Teacher non-verbal behaviours are considered by Mehrabian (1981) as even more important components of classroom communication than verbal behaviours. Their effect on pupil comprehension of verbal communication was not taken into account in this study.

The high incidence of technical terms associated with science may mask the effect of other language complexity.

The use of secondary classroom language calls for investigation in more precise terms and in greater depth than attempted in this study. It would be interesting to carry the investigation into other discipline areas to test the theory held by Barnes that the results might be similar over other curriculum areas.

CONCLUSION

In conclusion the results indicate that, in the early grades of the secondary school, the wide range of terms introduced into the teaching of science not only to maintain the precision of the discipline, but also to arouse the interest of pupils, need not be too limited. Satiation of the pupils' abilities to assimilate the concepts and to manipulate them in thinking can be overcome by presentation with explanations. Further, an inference can be drawn from the evidence that the introduction of explained concepts increases the learning of pupils.

The results have been applied in the training of a limited sample of beginning science teachers. After viewing demonstration tapes and discussing results the trainees exhibited increased interest and willingness to spend time in analysing their language and to use concept-mapping as pre-lesson aids to improvement.

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NONVERBAL BEHAVIOUR OF CLASSROOM TEACHERS AND ITS INFLUENCE ON PUPIL TASK-INVOLVEMENT

Janice M. Wilson and J.E. Butler

INTRODUCTION

The influence of the social and emotional climate of the classroom on learning has been the subject of many studies (e.g., Rosenshine, 1971; Duncan and Biddle, 1974). The research instruments used in many studies (Withall, 1949; Amidon and FLanders, 1963; Amidon and Hunter, 1967) have sought to examine the relationship between the behaviour of the teacher and such outcomes as pupil attitude and achievement. The behaviours of the teacher have been related to global variables such as teacher 'warmth', 'enthusiasm' and 'directiveness' and have been measured by examination of the statements made by teacher and pupil. Hence, only communication of 'warmth' and 'enthusiasm' via the verbal channel has been examined.

The importance of communication via the nonverbal channels has been recognised in recent years, chiefly for its role in the transmission of emotional states, attitudes and evaluations, which are not usually expressed verbally in interpersonal interactions.

We believe that previous studies of the verbal interactions between teacher and pupil in the classroom which have emphasised teacher 'warmth' and 'enthusiasm' have ignored the most important channels by which these states are communicated, i.e. the nonverbal channels.

Estimates of the relative importance of the nonverbal channels in other contexts have varied from 30 percent (Birdwhistell, 1970) to 93 percent (Mehrabian and Wiener, 1967). Studies within the classroom by Balzer (1969) and Keith, Tornatsky and Pettigrew (1974) have provided evidence that the nonverbal component of classroom communication is more important than the verbal component.

Other classroom studies (Beebe, 1980) have focussed on specific nonverbal behaviours (e.g. facial affect displays, movement around the classroom, eye contact between teacher and pupil) and have shown that nonverbal variables play a major role in affecting student learning and student attitudes to learning.

In this study, we examine aspects of the nonverbal behaviour of the classroom teacher during expository teaching and their relationship to work involvement of secondary science classes.

THEORETICAL PERSPECTIVE

Semantic differential studies by Osgood, Suci and Tannenbaum (1957) have shown that human judgements of diverse samples of stimuli can be characterised by three dimensions; affiliation, arousal and potency.

Mehrabian and Russell (1974) proposed the theory that physical or social stimuli in the environment directly affect the emotional state of a person, thereby influencing his or her behaviour in it. They postulated that primary emotional responses to the environment can be expressed in terms of their pleasant/unpleasant, arousing/unarousing and dominant/submissive qualities and that they also serve as mediating variables in determining a variety of approach/avoidance behaviour in the person interpreting the environment such as work performance, paying attention, exploration or social interaction.

Mehrabian's (1981) thesis proposes that pleasure-displeasure, arousal-nonarousal and dominance-submissiveness are both necessary and sufficient for the description and measurement of any emotional state. Specifically, the pleasure dimension ranges from unhappiness at one extreme to happiness at the other. Arousal denotes a combination of physical activity and mental alertness and its extremes range from sleep to frantic mental activity and/or physical activity. The dominance dimension ranges from extreme feelings of lack of control or influence upon one's surroundings to feelings of being influential and in control.

We are concerned with the expressions of feelings of pleasure, arousal and dominance by the teacher as the primary social stimuli in the classroom environment and will examine their relationship to one behavioural response of pupils; their involvement in the task set by the classroom teacher. Significant causal relationships between task involvement of pupils and learning have been demonstrated by Harnischfeger and Wiley (1976) and Carroll (1963).

METHODOLOGY

Recording of data

Entire secondary science lessons at Grade 8, 9 or 10 level were videotaped: twenty-four teachers on four occasions in 1979 (N = 86) and twenty-eight teachers on four occasions (N = 98) in 1981. Simultaneous visual records of teacher and pupil behaviour were obtained by two videocameras; a manually operated camera tracking the teacher from the back of the room and a fixed camera focussed on the pupils from a corner in the front of the classroom.

The behaviour of six pupils chosen for visibility, distribution and non-adjacent location on the pupil tape was coded for task involvement continuously throughout the lesson by six trained coders. Hence, pooled task involvement figures expressed as percentages for the target pupils were available for any portion of the lesson.

Criteria used in the assessment of task involvement were described in detail by Butler, Beasley, Buckley and Endean (1980).

Selection of two minute samples of lessons

Portions of the teacher tape were chosen for study according to the following criteria:

(1) using the videotape as a guide, the first two minute sample of tape in which the teacher was performing in an expository style was located in which (i) the film was of adequate technical quality, (ii) there was continuous, uninterrupted interaction between teacher and class, (iii) the videoscreen contained a full head and upper trunk view of the teacher.
(2) using the audiotrack as a guide, the accompanying verbal discourse should be free from emotive content and be related to science subject matter only.

Portions of videotape which fulfilled all these requirements were copied on to a master videotape in a random order of teachers.

The semantic differential measures of emotional state

A semantic differential instrument developed by Mehrabian and Russell (1974) was used to interpret the emotional states being communicated by the teacher subjects (Table 1).

TABLE 1 Semantic Differential Instrument (Sample items only) (Mehrabian & Russell, 1974)

How do you think this teacher is feeling:

	Pleasure	
2	pleased	annoyed
5	hopeful	despairing
	Arousal	
7	stimulated	relaxed
9	frenzied	sluggish
13	vigilant	uninterested
	Dominance	
14	controlling	controlled
16	important	awed
19	domineering	helpless

Coders

Secondary school pupils (aged 15 or 16 years) previously unacquainted with the teacher subjects, were employed to interpret the emotional state of the subjects. The sex ration of coders was 1 : 1.

The coders were asked to indicate on a 5-point scale between 19 pairs of adjectives 'how they thought the teacher was feeling'. Factor analysis of the matrix of 19 items by 30 coders (1979) and 33 coders (1981) confirmed the factor structure reported by Mehrabian and Russell (1974) for a variety of environmental stimuli. Three factors with eigen-values greater than 1 explained 87 percent of the variance in 1979 and 87.8 percent of the variance in 1981. The three factors corresponded to the postulated dimensions of pleasure (50-60% variance), arousal (10-16% variance) and dominance (17-20% variance).

Inter-Coder reliability

The mean of the scores on the three scales P, A and D assigned to each teacher on a particular occasion by the coders was computed to serve as the best estimate for each of the three scales. These means represent the basic data for statistical treatment. The inter-coder reliability was computed by an analysis of variance technique to yield the intraclass correlation coefficient (Winer, 1972). Estimates of the reliability of mean values by the 33 coders for the three subscales of P, A and D were .95, .90 and .93 respectively for a sample of 20 of the 98 teacher/occasions. We consider these reliability figures to be very satisfactory.

Stability of teacher affect states

A sample of teachers who had been videotaped on four occasions was used for the calculation of stability coefficients, (16 on 4 occasions in 1979; 15 on 4 occasions in 1981). The repeated measures check of Winer (1972) yielded the following coefficients for the years 1979/1981, Pleasure 0.79/0.79, Arousal 0.77/0.87, Dominance 0.89/0.56 and Task Involvement 0.74/0.37.

RESULTS

To determine the degree of linear dependence of Task Involvement (TI) on Pleasure, Arousal and Dominance, stepwise multiple linear regression was carried out (Nie, Hull, Jenkins, Steinbrenner, and Bent, 1975). The order of inclusion of independent variables (scores of P, A and D) was determined by the respective contribution of each variable to the explained variance. The correlation matrices of TI for 1979 and 1981 are shown in Table 2.

TABLE 2 Correlation Matrices Showing Relationships Between P, A, D and Task Involvement for 1979 and 1981 Data.

		1979			
		TI	P	A	D
1981	TI		.11	-.09	.24*
	P	.20*		.64***	.59***
	A	.10	.40***		.45***
	D	.34***	.47***	.32**	

* P <.05

** P <.01

*** P <.001

Table 3 shows the results of the regression analysis. The amount of variance explained by P, A and D was 11.9 percent in 1979 and 12 percent in 1981. Consideration of the full model (including P, A and D plus interactions between P & A, P & D, A & D and P, A & D) increased the amount of variance explained to 22 percent for 1979 and 18.2 percent in 1981.

Significant F values for arousal and dominance were obtained in 1979 and dominance in 1981. A significant interaction between A & D was revealed in both sets of data.

Hierarchical F tests showed that interaction terms were having a significant influence on the 1979 data, but this was not apparent in 1981.

TABLE 3 Summary of Generalised Regression Analyses on Task Involvement

Variables in Regression	Task Involvement 1979 (N = 86)			Task Involvement 1981 (N = 98)		
	df	R2	F	df	R2	F
Pleasure (P)	1	.006	0.74	1	.000	.26
Arousal (A)	1	.052	5.70*	1	.002	.06
Dominance (D)	1	.059	5.93*	1	.118	8.50**
Model Including Pleasure, Arousal and Dominance	3	.119	3.70*	3	.120	4.25**
Residual	82	.881	-	94	.880	-
(P x A)	1	.059	3.69	1	.002	.006
(P x D)	1	.001	0.14	1	.001	.15
(A x D)	1	.035	7.28**	1	.057	5.00*
(P x A x D)	1	.005	0.62	1	.001	.07
Full Model	7	.220	3.15**	7	.182	2.83*
Residual	78	.780	-	90	.818	-
* P <.05 ** P <.01	Hierarchical F-test for significance of interaction terms F = 2.5* P <.05			Hierarchical F-test for significance of interaction terms F = 1.70 NS		

Hierarchical group analysis

The data were examined by hierarchical group analysis (Veldman, 1975) so that teacher/occasions were clustered into groups and the total within group variation underwent a minimal increase at each step. The optimal number of groups was decided by the researchers after consideration of the change in error estimate following the addition of each entity.

1979 data

The optimal solution produced three groups of teachers with means on P, A and D as shown in Table 4, in which F values reveal significant differences between means. The dependence of TI on D as shown earlier in the correlation matrix is apparent, as are the smaller intercorrelations between P, A and D.

TABLE 4 Hierarchical Group Analysis of Teacher/Occasions in WCA (1979)

Group	N	Mean P	Mean A	Mean D	Mean TI
1	28	-.01	-1.93	3.27	85.88
2	48	3.48	1.76	4.35	85.39
3	10	-2.13	-1.73	-1.28	75.03
Total	86	0.15	3.34	0.08	84.35
F		53.5	70.6	88.15	2.95
P		<0.001	<0.001	<0.001	<0.05
		All means sig. diff	Gr 2 Diff from Grs 1 & 3	All means sig. diff	Gr 3 sig diff from Grs 1 & 2

Similar treatment of the 1981 data produced five groups of teacher/ occasions (Table 5). The highest task involvement was obtained by Group 5, with high mean scores on P, A and D. A general trend of decreasing task involvement accompanies descreasing scores on P, A and D, largely attributable to the significant correlation between TI and D and to a lesser extent, P.

The 33 student coders were asked to complete a semantic differential card for a hypothetical teacher, one perceived as 'Ideal' in expository teaching. Mean values of the 33 scores for the 'Ideal' teacher have been plotted. It is interesting to note that the 'Ideal' profile approximates Group 5, with highest mean scores on P, A and D, the group with 94.0 percent task involvement.

DISCUSSION

Significant contributions to the variance in pupil task-involvement by teacher 'Dominance' were revealed by regression analyses of two independent data sets from 1979 and 1981. Dominance, in the sense used by Mehrabian (1981) refers to the feelings of control or influence upon one's surroundings, and contrasts with submissiveness, referring to lack of control or influence.

Significant correlations between Pleasure, Arousal and Dominance were apparent in our data although Dominance was shown to be the greatest source of variance explained in Pupil Task Involvement. The joint influence of the P, A and D could be seen in the profiles of groups of teachers, classified on the basis of their scores on these dimensions. Teachers able to communicate high levels of Pleasure, Arousal and Dominance obtained high levels of Task Involvement from their pupils.

TABLE 5 Hierarchical Group Analysis of Teacher/Occasions in WCA (1981)

H Group	N	Mean P	Mean A	Mean D	Mean TI
1	23	1.38	-2.07*	3.67	88.6
2	34	3.75*	0.54	4.90	88.1
3	12	-2.07	1.48	4.63	87.8
4	7	-2.35	-0.55	-0.87*	76.3*
5	22	6.08*	3.08*	5.99*	94.0
Total		2.57	0.54	4.41	88.65
F		72.35	42.1	52.55	3.67
P		<0.001	<0.01	<0.01	<0.01
'Ideal'		9.58	3.03	6.82	

* p <0.05 diff. from all other groups.

Mehrabian (1981) summarised the research on the behavioural manifestations of these dimensions. Pleasure-displeasure can be inferred from the facial expressions and quality of vocal expressions. Arousal combines mental alertness and physical activity. Specific cues include verbal activity through speech rate and volume, speech errors, voice tremor, muscle tension and rate of movement. Generally, dominance is conveyed with behaviours implying strength, comfort, relaxation and fearlessness, whereas submissiveness is communicated with behaviours implying weakness, smallness, discomfort, tension and fearfulness. Postural relaxation has been identified as a subtle indicator of dominance: increasing degrees of asymmetry of body and limb position while standing or seated, or backward lean while seated communicate feelings of dominance. He proposed that combinations of levels of P, A & D could communicate specific emotional states. High levels of Pleasure, Arousal and Dominance communicate 'enthusiasm or exuberance', whereas low levels communicate 'anxiety'. Hostility may be expressed by low Pleasure, high Arousal and high Dominance.

Results of this study demonstrate the importance of the affective component of classroom communication and we have shown that these emotional states can be transmitted nonverbally.

Bassett and Smythe (1979) identified three functions of nonverbal cues in education:

(1) self-presentation in the role of teacher,
(2) identification of classroom norms and expectations,
(3) the feedback and reinforcement process.

Our study has illustrated a fourth function, viz. the communication of emotional states, attitudes and evaluations between teacher and student, and that they have a significant influence on pupil task involvement and hence learning.

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LACK OF BACKGROUND IN SCIENCE: IS IT LIKELY TO ALWAYS ADVERSELY AFFECT THE CLASSROOM PERFORMANCE OF PRIMARY TEACHERS IN SCIENCE LESSONS?

David Symington

INTRODUCTION

An issue which emerges almost every time science in the primary school is discussed is whether the limited scientific background of the vast majority of primary teachers spells doom for primary science. A number of researchers have attempted to provide a data base for such discussions (e.g. Crossland, 1972; Henry, 1977; Perkes, 1975). There are several reasons why no clear cut conclusions have emerged from this research. These include the difficulty of developing valid measures of the variables concerned and the diversity of the primary science programmes currently in use.

This paper presents data which support a view that, because there are abilities possessed by some teachers which can, in certain situations, compensate for any lack of scientific knowledge, no simple conclusions about teacher background should be expected.

CONTEXT OF THE STUDY

There have been a number of science programmes developed (e.g. Nuffield Junior Science and Science 5/13 in the United Kingdom, and the science course introduced in Victoria in 1970) which have suggested that much of the classroom activity in science should be attempts to solve, by investigation, the problems children pose. Such problems, that is those to which upper primary pupils could find a meaningful answer by practical investigation, are called Investigable Problems in this paper.

The course developers did not expect that every class of pupils would, unaided, be a steady source of such problems. Rather, they expected that often the teacher would create conditions which would stimulate Investigable Problems.

One Science 5/13 handbook (Science 5/13, 1972), for example, advises teachers that a 'fruitful source of inspiration for children is a discovery or display table where interesting things can be left for children to handle'. (p.6) In addition, the same author suggests that 'a certain amount of stage- management may still be needed'. (p. 6). By this he appears to mean that some selection of materials is desirable. He cites as an example:

> 'A strip of iron and a strip of aluminium already bent prompted Jane to try to bend both and she discovered that the aluminium was easy to bend but that the iron was beyond her strength'. (p. 6).

In the example just quoted the fact that the pupil could bend one metal strip but not the other drew her attention to strength as an investigable property of metal strips. Many similar examples can be found in the curriculum materials of the programmes being considered (see Symington (1980) p. 112). It seems, therefore, that it would be useful for teachers to have the ability to select, for free play by pupils, materials which direct the pupils' attention to an investigable property e.g. the sizes of drops as a property of liquids.

This leads to the question: Is primary teachers' lack of scientific knowledge likely to be an impediment to them developing this ability?

This question is the focus for this research. The research consists of a test of a model developed to take account of the differing backgrounds of teachers.

THE MODEL DEVELOPED AND TESTED

The model (Figure 1) which provided the base for the data collection was developed by considering the knowledge and skills teachers might use in deciding what materials they would provide for pupils to construct pendulums for a period of pupil-directed exploration.

The model deals only with factors in relation to one property of pendulums, that is the frequency. It was assumed first that some teachers will know of the relationship of this property to the length of the pendulum and the weight of the bob while others will not. It was further assumed that teachers who do know the relationship will differ amongst themselves:

(i) in their knowledge of what pupils will think are the factors which affect the frequency; and
(ii) in their ideas about what pupils should know about factors which affect the frequency.

With respect to teachers who do not themselves know the relationship the model assumed that they will differ amongst themselves:

(i) in that some will be aware of frequency as a variable whilst others will not, and
(ii) in whether they think that changes in the length and/or weight may influence some movement variable.

The model was designed to establish the likely outcomes of all of these possibilities. When the model was completed it became apparent that teachers with great differences in their knowledge and ideas about pendulums could be expected to arrive at the same outcome, the choice of a particular set of materials. For example, Path 1 describes a teacher who knows the relationship between frequency, length and weight, who knows that pupils are likely to think that the weight of the bob will influence the frequency and believes that this misconception should be corrected. Such a teacher could be expected to provide materials which would allow pupils to explore the impact on frequency of changes in the length of the pendulum and the weight of the bob (Materials A). Paths 3, 5, and 9 indicate how teachers with different knowledge, ideas and skills would be likely to provide the same materials.

That is, the model suggests that there will not be a simple, direct relationship between knowledge of the relationship between frequency, length and weight and the classroom outcome, the provision of materials for pupils. It shows how other ideas and skills can compensate for lack of science background knowledge. To test the model it was proposed to collect three sets of data (and to examine the relationships between them):

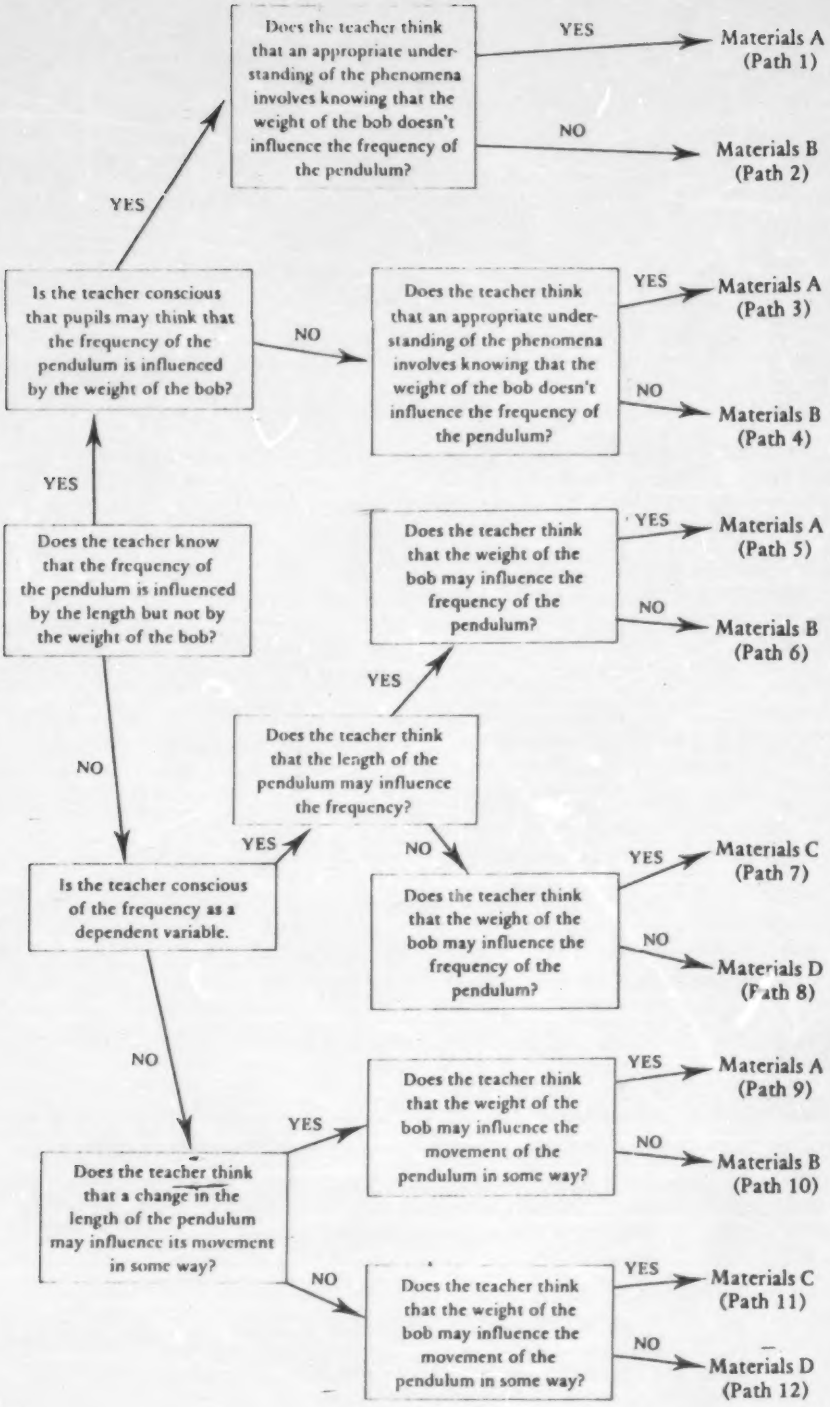
Does the teacher think that an appropriate understanding of the phenomena involves knowing that the weight of the bob doesn't influence the frequency of the pendulum?
YES
Materials A (Path 1)
NO
Materials B (Path 2)
YES
Is the teacher conscious that pupils may think that the frequency of the pendulum is influenced by the weight of the bob?
NO
Does the teacher think that an appropriate understanding of the phenomena involves knowing that the weight of the bob doesn't influence the frequency of the pendulum?
YES
Materials A (Path 3)
NO
Materials B (Path 4)
YES
Does the teacher know that the frequency of the pendulum is influenced by the length but not by the weight of the bob?
Does the teacher think that the weight of the bob may influence the frequency of the pendulum?
YES
Materials A (Path 5)
NO
Materials B (Path 6)
YES
Does the teacher think that the length of the pendulum may influence the frequency?
NO
YES
Is the teacher conscious of the frequency as a dependent variable.
NO
Does the teacher think that the weight of the bob may influence the frequency of the pendulum?
YES
Materials C (Path 7)
NO
Materials D (Path 8)
NO
YES
Does the teacher think that a change in the length of the pendulum may influence its movement in some way?
Does the teacher think that the weight of the bob may influence the movement of the pendulum in some way?
YES
Materials A (Path 9)
NO
Materials B (Path 10)
NO
Does the teacher think that the weight of the bob may influence the movement of the pendulum in some way?
YES
Materials C (Path 11)
NO
Materials D (Path 12)

Figure 1: Model constructed to describe pathways which can lead to the materials teachers choose for pupil free play.

Key to Figure 1

Materials	The teacher is likely to provide for a period of free play:
A	strings of various length and bobs of various weight.
B	strings of various length but not bobs of various weight.
C	bobs of various weight but not strings of various length.
D	neither strings of various length nor bobs of various weight.

(i) the materials suggested by teachers as suitable for pupil-directed investigation of pendulums;
(ii) the knowledge of the teachers of the relationship between the frequency of the pendulum, its length and the weight of the bob; and
(iii) the Investigable Problems about pendulums which the teachers could envisage.

The model could be tested by considering teachers who suggested the provision of materials which would allow pupils to investigate the impact of changing the length of the pendulum. The model leads to the prediction that these teachers will differ amonst themselves both in their specific knowledge of the phenomenon and in the Investigable Problems they are able to envisage.

THE SAMPLE

The sample for the study comprised 64 students in three of the science method classes, in the third and final year of the pre-service course at Toorak State College, taught by the author. These classes were not formed by random assignment of students but on the basis of time-tabling requirements. However, each class was likely to be fairly representative of students in that year of the course.

RESEARCH HYPOTHESES

The model suggests the following research hypotheses.

Hypothesis 1:
Student teachers who know the relationship between the frequency of the pendulum, its length and the weight of the bob will not differ from fellow students who lack this knowledge, in the materials they provide for pupil free play.

Hypothesis 2:
Student teachers who suggest that pupils be provided with materials which allow opportunity to observe the movement of pendulums with different lengths will differ from one another in the recorded Investigable Problems which involve the length of the pendulum.

METHODS OF DATA GATHERING

The data gathered in this study were obtained in a paper and pencil exercise. There were three parts to the procedure. First, after being provided with a definition of Investigable Problems, the subjects were given examples of Investigable Problems on the topic of magnets. They were then asked to record Investigable Problems on the topic of pendulums. A period of three minutes was allowed for this task.

Second, the subjects were asked to list the materials they would like to have available for one group of four, fifth or sixth grade pupils so that, as a result of a short period (10 minutes) of free play with the materials, the pupils could identify some Investigable Problems about pendulums. They were asked to make a list detailed enough for someone else to get the equipment together. There was no time limit imposed for this section of the task.

Finally, the subjects were asked to answer two questions designed to test their knowledge of whether the frequency of the pendulum is influenced by the length of the pendulum and/or the weight of the bob.

ISSUES OF VALIDITY

1. Paper and pencil procedures

There are obviously questions of validity to be considered when such paper and pencil procedures are used.

The first part of the procedure was to ask the teachers to record Investigable Problems on pendulums. There is no validity problem associated with the use of such procedures for this part since in practice this would be something happening in the mind of the teacher when thinking about providing materials for free play. For the study the student teachers have been asked merely to make a written record of the problems which come to their minds.

The validity of the second part, the listing of materials for free paly, is not dealt with so easily. There is a step between choosing the materials and the child interacting with them, namely the arrangement of the materials chosen. For example, the teacher may decide to supply bobs of differing weight for free play by the children. However, there is the further decision as to how to present the materials to the pupils. For example, the bobs may be simply placed on a table together with some string, or they may be suspended from strings of different length, The outcome of the free play may depend on this decision. This point needs to be borne in mind when the results are considered.

2. Handling lists of materials

When asked to suggest materials for pupil free play the student teachers were told that they should be specific. they were asked to 'make the list detailed enough for someone else to get the equipment together'. The result of the instruction meant that there were few difficulties in making decisions about the lists provided. Most of the subjects recorded items such as 'strings of different lengths', 'bobs of different weight'. (They were provided with the word 'bob'). Where there was any doubt in the minds of the researcher about the list provided, the problems suggested by the subject were examined. For example, where students' equipment lists contained string and ruler, the lists of problems suggested by the students were examined to see whether they contained reference to the different lengths of the pendulum. If they did then the materials were classed as providing the opportunity for pupils to observe the impact of a change in length on the movement of the pendulum. The

ultimate test of whether the pupils would use the materials to look at the impact of a change in length lies, of course, in the classroom. To use as a check the problems the teacher proposed rested on the belief that teachers are likely to influence pupil free play, not only through the materials, but also through verbal exchanges between teacher and pupils. These verbal exchanges are often likely to be very much influenced by the teacher's ideas of potential problems on the topic.

3. Test of Knowledge

Students were assessed as understanding the relationship if they gave the appropriate answer to both questions asked.

RESULTS

TABLE 1 Comparison of the number of student teachers who understand the relationship between the frequency of the pendulum, its length and the weight of the bob (Category A) and of those who lack such an understanding (Category B), with respect to the provision of materials which allow pupils to explore changes in (i) the length of the pendulum; (ii) the weight of the bob.

The materials to be provided for free play make provision for pupils to change	Number of student teachers in Category A	Number of student teachers in Category B
(i) the length of the pendulum	20	19
(ii) the weight of the bob	12	17

The results obtained when the link between background knowledge of the student teachers and the provisions they suggested for pupils through their choice of materials are presented in Table 1. When χ^2 tests were applied these indicated that there was no significant difference between the groups of students on either measure.

Table 2 presents the results obtained when the response of those students making provisions for change in the length of the pendulum were inspected to note the Investigable Problems which specifically referred to the expected impact of these changes. Very similar results were obtained when a comparable analysis was made with respect to provisions for change in the weight of the bob (see Symington, 1980).

The analyses of the data clearly show that the choice of materials has been influenced by a range of problems. For example, the provision of pendulums of differing lengths was suggested not only by students who believed that the length may influence the frequency but also by others who believed that the length may influence the time it takes the pendulum to come to rest.

TABLE 2 The problems suggested by student teachers (n = 39) who provided materials which allowed for a change of length of the pendulum

	Problem recorded	Number of students whose materials provided for a change of length
(i)	Does the length of the pendulum influence the movement of the pendulum?	8
(ii)	Does the length of the pendulum influence the speed/frequency of the pendulum?	20
(iii)	Does the length of the pendulum influence the size of the swing?	2
(iv)	Does the length of the pendulum influence the length of time before it comes to rest?	6

DISCUSSION OF RESULTS

The data show that the provision of appropriate materials for pupil free play does not bear a simple, linear relationship to background scientific knowledge. They thus support the view that there are abilities possessed by some teachers, for example, the ability to devise Investigable Problems, which can, in certain circumstances, compensate for a lack of scientific knowledge.

Research into the impact of the background knowledge of teachers on their ability to handle primary science must move beyond the rather simplistic approach which has often been adopted in the past. Researchers should identify the roles in which teachers are expected to engage and look at the influence not only of teacher knowledge but also of other relevant skills on teachers' ability to fulfil these roles.

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Research in Science Education, 1982, 12, 71-77

A PERSPECTIVE ON THE DIFFERENCES BETWEEN EXPERT AND NOVICE PERFORMANCE IN SOLVING PHYSICS PROBLEMS

Audrey B. Champagne, Richard F. Gunstone, and Leopold E. Klopfer

INTRODUCTION

There has been in recent years a dramatic growth of investigations of student world views of force and motion. These investigations, often motivated by a concern with student understanding of mechanics, have reflected a world-wide interest in these issues (e.g., Champagne, Klopfer and Anderson, 1980; Driver, 1980; Gunstone & White, 1980; Hewson, 1981; Osborne & Gilbert, 1979). The existence of world views logically antagonistic to the tenets of mechanics is now beyond dispute, as is the resilience of these views in the face of standard forms of physics instruction. It seems clear that the significant issues in this area are now the specific instructional implications of these findings.

THE INSTRUCTIONAL PROBLEM

Classical mechanics is widely perceived to be difficult to learn. Researchers considering this phenomenon have often investigated particular variables argued to be prerequisite to successful physics learning, such as mathematical skills, general level of cognitive development, and specific cognitive processes (e.g., Arons, 1976; Hudson & McIntire, 1977; Renner, Grant & Sutherland, 1978). The usual basic strategy adopted in such investigations is to show a correlation between a student characteristic (such as Piagetian level of cognitive development) and success in physics. Often instruction is then modified to take account of student inadequacies with respect to this concept, and the effect of this modification on learning is probed. However this strategy has produced only limited results (e.g., Mallinson, 1977; Peterson, 1979).

The studies of student world views of force and motion mentioned above provide another perspective on the difficulties involved in learning physics. These studies give empirical support to arguments that students come to introductory physics courses with firmly embedded conceptualisations of how and why objects move. The conceptualisations have features which are broadly Aristotelian. Many writers have commented on the historically great effort involved in replacing the Aristotelian view of motion in physics. Dijksterhuis (1961) goes further:

> To this day every student of elementary physics has to struggle with the same errors and misconceptions which then had to be overcome, and on a reduced scale, in the teaching of this branch of knowledge in schools, history repeats itself every year. The reason is obvious: Aristotle merely formulated the most commonplace experiences in the matter of motion as universal scientific propositions, whereas classical mechanics, with its principle of inertia and its proportionality of force and acceleration, makes assertions

> which not only are never confirmed by everyday experience, but whose direct experimental verification is fundamentally impossible ... (p.30).

The research described in this paper leads to an instructional design approach which is an alternative to consideration of issues such as mathematical skills or level of cognitive development. The approach uses an analysis of traditional instructional tasks for the purpose of specifying the underlying cognitive processes and structures necessary for the successful completion of the tasks. That is, a cognitive analysis of instructional tasks, rather than a logical analysis, is used to arrive at appropriate instructional goals. In particular, we consider two broad aspects of differences between physics experts and novice physics students which are relevant to physics problem solving. These aspects come from recent cognitive psychology research into processes and structures used by experts and novices in physics problem solving, and from science education research into student world views. From these we advance simple models of expert and novice physics problem solving and then use these models to consider appropriate goals for physics instruction.

EXPERT AND NOVICE PROBLEM SOLVING

The focus here is on problem solving studies undertaken in the area of physics. We have discussed elsewhere both studies in other subject areas and the implications of the broader context of current views that learning is an active and constructive process, that existing knowledge/schema are of considerable importance to the process of coming to understanding through individual interpretation of material to be learned (Champagne, Klopfer and Gunstone, 1982).

Larkin (1979) analysed thinking-aloud protocols obtained from experts and novices while they solved physics problems. She found that experts perform an initial qualitative analysis of a problem before using appropriate equation(s) for the quantitative solution of the problem. Novices, by contrast, immediately search for an equation and do this by matching the information given in the problem with terms in the equation. This difference in problem solving process is shown in simple form in Figure 1.

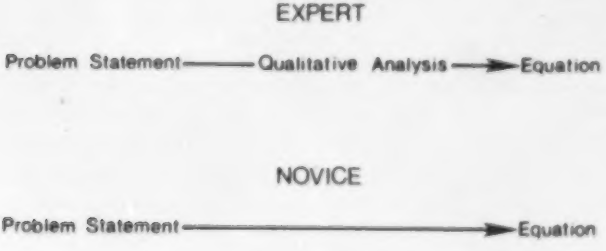

Figure 1: Expert and novice problem solving strategies.

It is not only for problem solving processes that expert/novice differences are found. A series of experiments by Chi, Feltovich and Glaser (in press) has resulted in descriptions of explicit differences in the physics problem solving schemata of experts and novices. In the first of these experiments, subjects were asked to sort physics problems from a commonly used text by whatever criteria seemed appropriate. Novices were found to sort on the basis of the problems' surface structure (objects such as springs and inclined planes; terms such as friction; similarities between diagrams), while experts sorted on the basis of the problems' deep structure (laws of physics such as Newton's Laws) that are not mentioned specifically in the problem. A replication and extension of this experiment, which verified that the problem schemata of novices are object-oriented while the schemata of experts are principle-oriented, included advanced novices. These advanced novices sorted problems on the basis of principles, but used surface features to rationalise their sorts. This suggests a continuum from object-oriented to principle-oriented schemata. The findings are also consistent with the view that novices have a number of different schemata which might be applied to situations involving motion, while experts have a single schema for such situations. Such a view would then have that the process of moving from novice to expert involves, in part, the collapse of and integration of multiple schemata into a single schema. The interpretation is also consistent with the phenomenon observed in studies of student world views of novices switching between an Aristotelian schema and a Newtonian schema as they move from one situation involving force and motion to another.

Chi et al. also asked subjects to elaborate on the concepts and problem features that had been used as a basis for categorisation of the problems. These data indicate that the novices have the same information about the physical principles as the experts, but novices fail to link objects and concepts with physical principles because the necessary relations between these elements are lacking. In contrast, for the expert, the description of a physical situation immediately evokes an applicable physical principle. This suggests that the expert has information relating to conditions under which the principle is applicable and this information is associated with the principle. Further, there is evidence that the expert's knowledge is organised hierarchically along the dimension of abstractness, a characteristic which allows for either bottom-up or top-down processing. The novice's less-integrated structure does not allow for such flexible accessibility.

The purpose of the fourth experiment in the Chi et al. study was to determine the features of the problems on which the experts based their selection of the appropriate physical principle for solution of the problem. The results of the experiment reveal a significant difference in the degree of abstractness of expert and novice representations of problem types and features. Experts immediately abstract a basic solution strategy from the surface features of the problem. In contrast, novices do not distinguish between the plan for the solution of the specific problem and the existence of a general solution plan for the problem type. Further, experts mention transformed or abstracted features while the novices described the specific objects and physical constructs. This suggests that the expert translates the literal objects and conditions of the problem into canonical objects and, on the basis of this representation, selects the prototypical problem type of which the particular problem is a specific example.

In summary, the Chi et al. study concludes that the following differences characterize schemata that expert and novice physicists apply in the solution of physics problems: (1) The problem-type schemata of experts are based on

physical principles (e.g., energy conservation), and those of novices are based on physical objects (e.g., springs and inclined planes) and constructs (e.g., friction and gravity). (2) The contents of the schemata of experts and novices do not differ significantly in information content; however, the novices' structures lack important relations, specifically relations between the surface features of the problem and the scientific principles which are the basis for solutions. (3) Experts translate surface features of the problems into canonical objects, states, and constructs while the novices represent the problem in terms of the literal objects and constructs described in the text of the problem. (4) Links exist in the experts' representations of knowledge structures between the abstract representation of features of the problems and the physical principles which are the basis for the solution of the problem. (5) Experts' schemata are arranged hierarchically along the dimension of abstractness; in contrast, the different levels of the novices' knowledge are not well integrated, thus preventing easy access from one level of abstraction to another.

Views of force and motion held by physics novices

The results of studies such as those cited in the introduction are briefly summarised here.

Students of physics have descriptive and explanatory systems/schemata for how and why objects move which develop before formal instruction. We shall call these novice schemata "intuitive" systems. Although the intuitive systems differ in significant ways from the systems to be learned in physics (experts' schemata), the two systems use similar vocabulary. However, the meanings attached to terms by novices are not in one-to-one correspondence with the physics meanings (e.g., acceleration, force). Intuitive systems frequently co-exist with ideas derived from instruction, even among successful physics novices. This co-existence is often possible because novices learn the physics systems at the verbal level only. It is also clear that intuitive systems can influence observations by novices of physical situations.

Models of expert and novice problem solvers

By combining these details of differences between physics experts and novices with the conclusions of the Chi et al. study it is possible to elaborate the initial model of expert/novice problem solving shown in Figure 1. The resulting models, shown in Figure 2, are still simple representations. It should be noted that the two schemata depicted in the novice model are most likely to be several schemata. The evidence is strong that a novice will have both a number of schemata derived from the real world and a number of schemata derived from physics instruction.

By comparing these representations of experts and novices, we can deduce some appropriate goals for the teaching of physics problem solving skills to novices. In broad terms, these are the development of appropriate schema change and integration, and the acquisition of strategies of qualitative analysis. It is clear that the first of these (schema change) is not an easy goal to achieve. Our own early attempts, based on a more general consideration of the problem, have met with only limited success (Gunstone, Champagne and Klopfer, 1981). It is also clear from inspection of introductory physics courses and texts that the second goal (qualitative analysis) has previously received little, if any, attention.

In the concluding section of the paper we briefly consider some instructional implications of these goals.

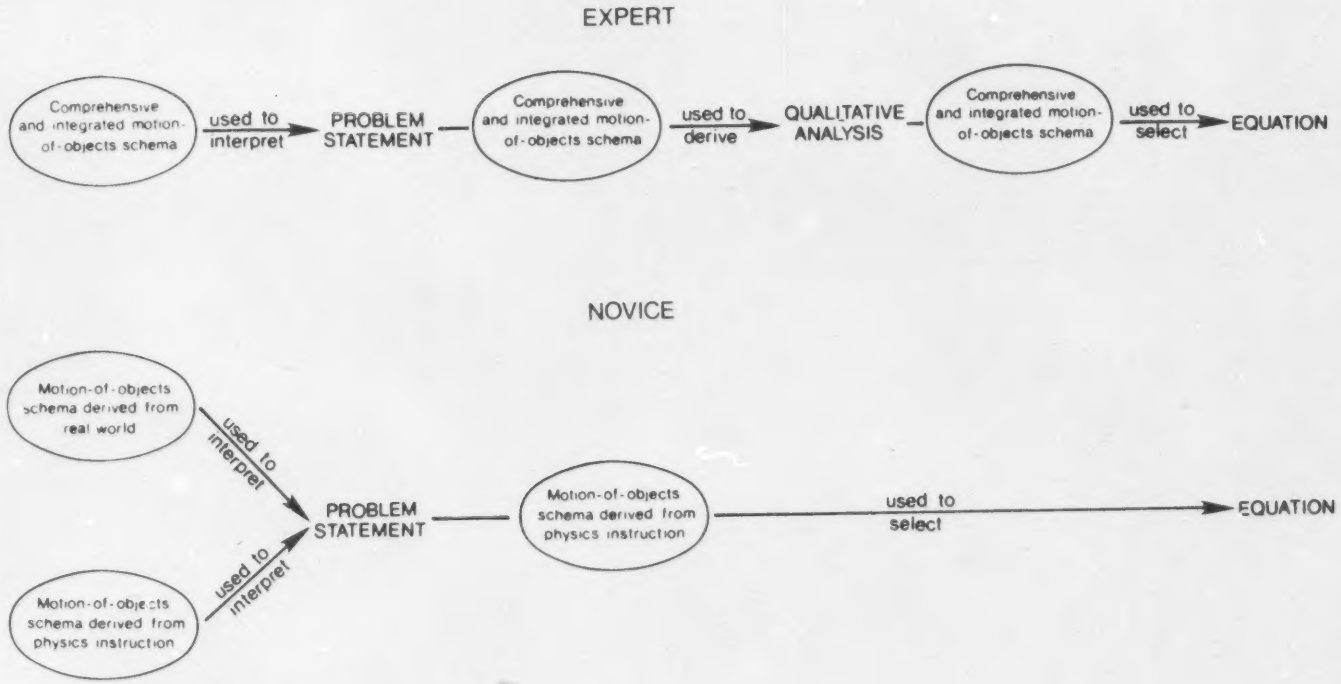

Figure 2: Problem solving strategies and schemata of expert and novice

INSTRUCTIONAL IMPLICATIONS

An obvious question resulting from the above is "what experiences do experts have which might result in the described differences?" There appear to be three forms of such experience:

(1) additional formal instruction; (2) more practice in solving problems; (3) more extensive verbal interactions about physics or more experience in organizing physics information for the purpose of communicating it to others. For two reasons the third of these is the most interesting from the perspective of instructing novices. Firstly, it is the only one which is readily translated into an instructional context for an introductory physics course. Secondly, as discussed above, it is the links in experts' knowledge structures rather than the knowledge itself which appears to distinguish experts and novices - and the prospect of enhancing the development of such links in novices through verbal interaction and communicating to others about physics is, at the very least, logically reasonable. Further, current views of the process of schema change support the proposition that a dialectical process appears to be necessary (e.g., Anderson, 1977; Collins & Stevens, 1982).

As a consequence of these arguments, we hypothesize that an instructional dialogue based on the qualitative analysis of problems holds promise for the attainment of the two broad goals listed above. Some specific examples of such an instructional form have been given elsewhere (Champagne et al., 1982). In summary, the approach involves taking a standard form of question, such as a rifle and bullet question where a numerical value for recoil velocity of the rifle is asked for, and converting it to a qualitative problem, such as asking how the speed with which the bullet leaves the rifle compares with with speed of the rifle at that time. (This also brings the question somewhat closer to a general problem for than is the more normal numerical example.) Appropriate levels of existing relevant knowledge and experience are then determined, and a series of questions and specific, single-observation laboratory exercises are used to gradually develop a schema for the problem solution. The interaction implicit in the strategy allows for the retention of appropriate aspects of existing schemata and the modification of conflicting aspects. The next stage of our work will involve an investigation of the extent to which our instructional forms can achieve these goals.

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WHAT LOWER SECONDARY STUDENTS SHOULD UNDERSTAND ABOUT THE MECHANISMS OF INHERITANCE AND WHAT THEY DO UNDERSTAND FOLLOWING INSTRUCTION

Mark W. Hackling and David F. Treagust

INTRODUCTION

Human genetics is considered to be an important aspect of the general education of all citizens as genetic inheritance has implications for the areas of health, family planning and childbirth (Biological Sciences Curriculum Study, 1978). Genetics is a usual component of the secondary science syllabus but is considered by many teachers to be one of the most difficult biological science topics for students to comprehend. Indeed, learning difficulties posed by school genetics topics and the importance of genetics in general education have acted as stimuli both for research studies into the learning of genetics (Deadman and Kelly, 1978; Emery, 1973; Kargbo, Hobbs and Erickson, 1980; Walker, Mertens and Hendrix, 1979) and for the development of new curriculum materials (Biological Sciences Curriculum Study, 1980).

During the past decade, a number of research studies have attempted to probe and describe students' understanding of a wide variety of science concepts. Many of these studies (Nussbaum and Novak, 1976; Osborne and Gilbert, 1979; Stead and Osborne, 1981) involved interview techniques based on models, diagrams or drawings which provided a focus for discussion and a means to probe the students' understanding of the concepts under investigation. According to Ausubel, Novak and Hanesian (1978), concepts are defined as classes of objects, events or properties that possess common criterial attributes and are designated in any given culture by some accepted sign or symbol. Novak (1980) believes that concepts are learned meaningfully when the new concept is linked by propositions to other relevant concepts that are already established in cognitive structure. Concepts grow in meaning as they are related to other concepts by meaningful propositions; propositions also gain meaning as the component concepts gain meaning.

In order to investigate secondary students' understanding of genetic inheritance following a course of study in genetics, the concepts and propositions involved were identified. The prime focus of this investigation involved individual student interviews to identify those concepts and propositions that are poorly understood and limit students' understanding of inheritance (Hackling, 1981).

Two research questions were addressed in the investigation:

- Which concepts and propositions are necessary for students to comprehend the mechanisms of inheritance at the level of sophistication of meaning expected of year 10 students in Western Australia?
- Which of the inheritance concepts and propositions are most frequently not understood or misunderstood and therefore limit students' understanding of the mechanisms of inheritance?

METHOD

Identification of Inheritance Concepts and Propositions

Three lecturers in science education independently identified the concepts considered necessary for understanding inheritance; subsequently, each lecturer prepared a concept map based on the identified concepts. The concept maps together with the Teachers' Guide for the Lower Secondary Science Genetics topic (Education Department of Western Australia, 1972) were analysed to identify a sequence of propositions which could lead to an understanding of inheritance. Eighteen propositions were identified at the level of sophistication of meaning expected of Year 10 students. The eighteen propositions (Table 1) were cross-validated as to their relevance for an understanding of the mechanisms of inheritance by tertiary lecturers in genetics and by secondary biology teachers.

Instrument Development

Three pilot studies were conducted to develop and trial the interview instrument, and to identify a small number of inheritance concepts that might be poorly understood. The Inheritance Concepts and Propositions Interview (ICPI) instrument was designed to explore and assess students' understanding of the 18 propositions and the five concepts of 'inheritance' (C1), 'locus' (C2), 'meiosis' (C3), 'fertilization' (C4), and 'mitosis' (C5). The content validity of the instrument was ensured by basing its construction on the previously validated list of 18 propositions; three science educators evaluated the instrument to ensure its construct validity.

The Interview

The ICPI is a partially standardized interview instrument consisting of a set of figures that are shown to the students, and a series of statements and probing questions on cards that are read out by the interviewer. The students were individually interviewed several days after they had completed the genetics topic; each interview was tape recorded with the permission of the student. Many of the probes required students to apply their understanding of concepts and propositions to explain a novel situation. Whenever students were required to select from a range of alternative answers, or to make a judgement of any kind, they were always asked to explain the reason for their choice or judgement. These explanations revealed the level and extent of student understanding of a particular idea.

Each of the concepts and propositions was analysed to identify its component sub-ideas. The ICPI instrument probed each of these sub-ideas so that students' understanding of aspects of a concept or proposition could be explored and recorded in such a way that credit could be given for partial knowledge of a complex proposition.

Subjects

A modified stratified-random sampling technique was used to select a sample of 48 students in Year 10 (15 years of age); 12 students were selected from each of the achievement levels Advanced Credit, Advanced Pass, Intermediate Credit and Intermediate Pass. In Western Australia Year 10 students are streamed into three levels (Advanced, Intermediate and Basic) according to their achievement in science; students at each level earn grades of a pass or credit. The students were selected from six different schools and from 13 different science classes in the Perth metropolitan region.

TABLE 1 Propositions Necessary for an Understanding of the Mechanisms of Inheritance Defined at the Level of Sophistication of Meaning Expected of Year 10 Students

Proposition Number	Definition of Proposition
P1	The mechanism of inheritance passes charactertistics of parents to offspring during reproduction.
P2	Genes determine all hereditary characteristics of an organism.
P3	Genes for a given trait can exist in alternative forms.
P4	Genes are located on chromosomes.
P5	Genes carried by the sex chromosomes determine the sex of the individual.
P6	Males have the sex chromosomes XY and females the sex chromosomes XX.
P7	Many traits are determined by one pair of genes.
P8	Parental cells contain chromosomes in pairs and genes in pairs.
P9	A member of a gene pair is located on each member of a pair of chromosomes.
P10	Meiosis is the form of cell division that separates the pairs of chromosomes and pairs of genes of parental cells so that the gametes produced carry one chromosome and one gene from each pair.
P11	Gametes produced by a parent may differ genetically in that they can carry alternative forms of a given gene and different sex chromosomes.
P12	Gametes carry genetic information from both parents of one generation to the offspring of the next generation.
P13	Fertilization of haploid gametes restores chromosome and gene pairs, and the normal diploid number of chromosomes in the zygote which is produced.
P14	Chance determines which of the sperm fertilizes each of the eggs and therefore the genotype of the offspring.
P15	Offspring (sexually produced) differ from each of their parents as they contain a mixture of genes from both parents.
P16	Dominance relationships between genes influence the expression of genes in the phenotype; recessive genes may be masked and in the case of incomplete dominance blending may occur.
P17	Environmental factors influence the development of offspring and control the extent to which the genetic potential of the individual is achieved.
P18	the multicellular adult organism develops from a single-celled zygote by mitotic cell division hence all body cells of a given offspring have the same number and type of chromosomes and genes.

Each of the science teachers involved in the study based their instruction on the Lower Secondary Science Genetics topic Teachers' Guide (Education Department of Western Australia, 1972). Year 10 students in Western Australia study a six week genetics topic which focuses on the mechanisms of inheritance; applications of genetics to medicine and agriculture are also briefly considered. Intermediate and Advanced level students were taught the same range of concepts but teachers tended to vary the level of instruction according to the ability of their students.

Analysis of Data

Each of the sub-ideas probed in the interview was identified and listed. The tapes were replayed and each of the students' responses was coded for understanding as comprehension (C), recall (R), lack of knowledge (-) or misunderstanding (M) of the sub-idea. The comprehension (C) category included responses that indicated comprehension or application of the idea, as defined by Bloom (1956). Students' responses that represented knowledge of the idea (Bloom, 1956) were coded as recall. The lack of knowledge category (-) included responses that indicated the student did not know the idea or the student's responses were inconsistent and contradictory. When students provided explanations indicating that they misunderstood a particular idea, their response was coded (M).

Scorer Reliability

The reliability of the coding procedure for students' understanding of the sub-ideas was determined by both inter-rater and intra-rater estimates. The primary investigator and two science educators were 87% and 83% concordant respectively on scoring student responses. The judgement of the primary investigator was corroborated by at least one of the science educators on 97% of instances. When the primary investigator scored the same tape on two occasions, separated by one week, 96% of the student's responses were scored identically. Scorer reliability was therefore not considered a serious threat to the reliability of the data.

RESULTS AND DISCUSSION

The data presented in Table 2 indicate the level and extent of students' understanding of concepts and propositions considered necessary to comprehend the mechanisms of inheritance. Eight propositions considered essential to an understanding of inheritance (P3, P7, P10, P11, P14, P16, P17 and P18), were fully comprehended by less than 25% of the students. At least one component sub-idea of each of these propositions was comprehended by less than 25% of the students.

Comprehension and Student Achievement Level

The student response data presented in Table 2 have been divided further into achievement levels of Intermediate Pass and Credit, and Advanced Pass and Credit. The proportion of total responses for students at a given achievement level scored at different levels of understanding are presented in Figure 1. The graphed data illustrate that there was an increasing level of understanding of the inheritance concepts and propositions amongst students from the higher achievement levels. Of particular interest is the dramatic increase in the frequency of comprehension and the decrease in "don't knows" and misunderstandings with students from the higher achievement levels. Despite this expected improved comprehension of the more able students, a surprising aspect of this investigation is the relatively low level of comprehension of concepts and propositions of inheritance amongst the 48 students.

TABLE 2 Students' Understanding Inheritance Concepts and Propositions (n=48)

Concept or Proposition Number		Idea/Sub-Idea	% of Students responding			
			C[a]	R[b]	-[c]	M[d]
C1	a	Children's features come from their parents	94	6	0	0
	b	Genes pass from parents to offspring to give the feature	77	15	8	0
P1	a	Inheritance and reproduction occur together	50	38	12	0
P2	a	Genes control the features of an organism	31	23	31	15
	b	Acquired features are not passed on to offspring	40	48	0	12
P3		Genes for a given trait can exist in different forms	4	27	69	0
P4		Genes are located on chromosomes	44	17	20	19
P5	a	Sex / XY chromosomes determine sex	27	8	32	33
P6		Males have the sex chromosomes XY and females XX	25	0	73	2
P7	a	Two genes control each features	13	32	15	40
	b	Some features are controlled by several pairs of genes	2	4	79	15
P8	a	Body cells have chromosomes in pairs	45	15	25	15
	b	Body cells have genes in pairs	63	19	4	14
P9		A member of a gene pair is located on each member of a pair of chromosomes	50	29	6	15
C2		Locus	27	15	41	17
P10	a	Gametes carry one chromosome and one gene from each pair	11	6	23	60
C3	a	Gametes are produced by cell division	8	4	88	0
	b	Gametes are made by meiosis	-[e]	10	90	0
	c	Eggs/sperm are made in the ovary/testis	-	67	33	0
	d	Sex cells are made in the flowers of plants	-	58	17	25
	e	The sperm (and egg) carry one gene for each feature	18	15	2	65
	f	The egg carries half the normal number of chromosomes	75	0	4	21
	g	One chromosome from each pair passes into the egg	10	0	69	21
P11	a	Gametes from a given parent do not all carry the same genes	10	48	21	21
	b	Gametes from a given parent may carry alternative genes for a given feature	10	15	56	19
	c	Gametes may carry different sex chromosomes	12	0	88	0
P12	a	Gametes carry the genes from parents to offspring	48	20	17	15

P13	a	Offspring have chromosomes in pairs and a pair of genes for each feature	40	15	22	23
C4	a	Fertilization involves joining of egg and sperm cells	52	13	35	0
	b	Fertilization restores the normal number of chromosomes	60	-	17	23
P14	a	Chance determines what genes/features the baby will have	16	13	4	67
P15		Offspring differ from each of their parents as they get a mixture of genes from both parents	44	29	27	0
P16	a	Dominance relationships between genes influence which gene of a pair is expressed in the phenotype	2	0	98	0
	b	Dominant genes are expressed in the phenotype	13	10	14	63
	c	Recessive genes can be masked by dominant genes	9	6	85	0
	d	Recessive genes are only expressed if the individual has two recessive genes for that feature	4	2	94	0
	e	Blending occurs when two genes are incompetely dominant	10	13	21	56
	f	Predicts the phenotype of BB, Bb and bb	73	-	2	25
P17	a	Environmental factors influence growth	56	23	21	0
	b	Genes influence growth	27	25	42	6
	c	Environmental factors influence the extent to which the genetic potential is expressed	0	0	100	0
P18	a	Growth involves cell division	42	6	44	8
	b	Growth involves mitosis	-	23	71	6
	c	All body cells of an individual have the same genes	13	12	10	65
	d	All body cells of an individual have the same genes as they were produced from the zygote by mitosis	2	0	98	0
C5	a	Mitosis is a form of cell division	38	10	52	0
	b	Each daughter cell has the same genes and chromosomes as the original cell	11	4	85	0

Note.
a. Understands the idea at least to Bloom's level of comprehension
b. Can recall the idea
c. Does not know the idea
d. Misunderstands the idea
e. The interview does not examine student's knowledge of the idea at this level of understanding

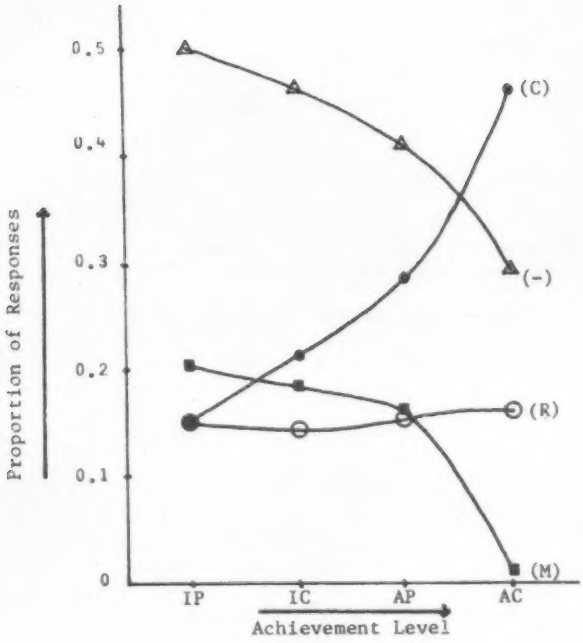

FIGURE 1 Proportion of total responses for students at a given achievement level scored at different levels of understanding

The Idea of Inheritance

Many students understand that inheritance and reproduction occur together (P1a, 50%C), that children's features come from their parents (C1a, 94% C), that genes for these features are carried to the offspring by the gametes (C1b, 77% C; P12a 48% C) so that offspring get a mixture of features from both parents (P15, 44%C). Many of these ideas could have been developed from observations of patterns of inheritance within the students' own families. These ideas can be learned from concrete experiences and this most likely explains why these ideas are more frequently understood than ideas relating to abstract phenomena such as the alternative forms of genes and dominance relationships (P16a, 2% C; P16b, 13% C) (Good, 1977).

The Influence of Genes and Environmental Factors on the Development of Individuals and their Features

The influence of environmental factors on the development of an individual's features was more frequently comprehended (P17a, 56% C) than the influence of genes (P17b 27% C; P2a, 31% C) on the development of features. Students have direct experience of the influence of environmental factors such as exposure to sunlight and its effect on the tanning of skin, and the effect of diet on body shape; whereas the action of genes cannot be readily observed.

The number of genes involved in the control of development of a given feature was comprehended by very few students. Few students understood that many features are controlled by one pair of genes (P7a, 13% C); only one student understood that some features are controlled by several pairs of genes (P7b, 2%C). The lack of awareness of polygenic inheritance may certainly be considered undesirable as many important human characteristics, such as the size and shape of the body, skin colour, intelligence and many inherited abnormalities, are controlled by several pairs of genes. Based on general conversations with teachers of the students involved in this investigation, it soon became clear that this idea was not being taught; the idea of polygenic inheritance is also only briefly mentioned in the local curriculum materials.

Alternative Forms of Genes and the Role Played by Chance in Inheritance

Propositions P3, P11 and P14 relate to the existence of alternative forms of genes (alleles), and ability of gametes to carry one of these alternative genes, and the influence of the chance recombination of gene pairs at fertilization on the genotype of offspring. Only two of the 48 students could apply an understanding of the existence of alternative forms of genes to explain the occurrence of distinctly different forms of a given feature (P3 4% C). Unless students understand the concept of gene in terms of information, it will be difficult for them to appreciate that there can be alternative sets of information to program the development of a given feature.

The sub-idea P11b, 'gametes from a given parent may carry alternative genes for a given feature', was probed in the context of explaining the variation between children within a family; only 10% of the students comprehended this sub-idea. Proposition P14, 'chance determines which of the sperm fertilizes each of the eggs and therefore the genotype of the offspring', was comprehended by 8% of the students. Students were asked to predict the hair texture of children produced by two hybrid parents. Only 17% of the students understood that chance influenced the outcome; 27% of students believed that three of the four children produced by these parents would certainly have the dominant feature. The teaching of the 3:1 phenotypic ratio as an outcome of the monohybrid cross would appear to be detrimental to students' understanding of the role played by chance in inheritance. The students' lack of comprehension of the 'law of large numbers' (Good, 1977) limits their ability to comprehend that in the small numbers of offspring found in the typical human family there will be marked deviations from the 3:1 phenotypic ratios which are based on large populations. The idea of phenotypic ratios is of historical interest but has limited applicability to human genetics. An understanding of the role played by chance is essential for effective genetic counselling.

The Pairing of Genes and Chromosomes, and the Separation of Gene and Chromosome Pairs During Meiosis

Propositions P8, P9 and P10, and the concepts of locus (C2) and meiosis (C3) relate to the existence of genes and chromosomes in pairs, the location of pairs of genes on pairs of chromosomes, and the separation of chromosome and gene pairs during meiosis so that gametes carry one chromosome and one gene from each pair found in the body cells of the parent. The majority of students were aware that chromosomes exist in pairs (P8a, 61% C+R), that genes exist in pairs (P8b, 82% C+R), and that one gene of a pair was found on each chromosome of a pair (P9, 79% C+R). The separation of chromosome and gene pairs by meiosis during the production of gametes so that the egg and sperm carry one chromosome and one gene from each pair, and the reformation of gene

and chromosome pairs at fertilization are central to an understanding of the mechanisms of inheritance. Only 10% of the students comprehended that gametes carry one chromosome and one gene from each pair (P10a); 48% of the students believed that gametes carry both genes and chromosomes from the pairs. These results corroborate the findings of Okeke and Wood-Robinson (1980) who reported that the difference between the number of chromosomes in somatic cells and gametes, and the reason for the difference, was the most poorly understood of the reproduction concepts that they tested amongst 120 Nigerian 16-18 year olds.

The majority of the students were not aware of the process by which gametes are produced. Only 12% of the students could recall that gametes are made by a process involving cell division, and only 10% of students could recall meiosis as being the name of the process by which gametes are made.

Dominance

Proposition P16 relates to the dominance relationships between genes; 73% of students could correctly predict the phenotype of individuals with the genotypes BB, Bb and bb (P16f) where 'B' and 'b' were the genes for hair colour. Most students found it very difficult to explain the meaning of the terms dominant, recessive and blending inheritance.

Growth of the Offspring

Proposition P18 and the concept mitosis (C5) relate to the role played by mitosis in the growth of the offspring from the zygote and the genetic equivalence of all body cells of an individual. The idea that growth occurs by a process of cell division was comprehended by slightly less than half of the students (P18a, 42% C); few students could associate the name mitosis with growth (P18b, 23% R). Sixty-five percent of the students believed that each type of cell that made up an individual's body had a different set of genes; few students comprehended that each of these cell types have the same genes (P18c, 13% C).

There are probably two factors that contribute to students' misunderstanding of the genetic equivalence of an individual's body cells. The first factor is a lack of understanding of the role played by mitosis in growth which ensures that all the new body cells produced during the growth of the individual have the same genes as the zygote. The second factor relates to gene regulation. Many students would argue that if a skin cell and a nerve cell have the same genes they should develop into the same type of cell. If they were aware that only the 'skin cell genes' are switched-on in the skin cell and only the 'nerve cell genes' are switched on in the nerve cell they could comprehend the process of differentiation. Based on conversations with teachers it appears that this concept is not being taught in schools.

IMPLICATIONS FOR TEACHING LOWER SECONDARY GENETICS

This study has provided information of direct relevance to teachers of lower secondary genetics. Several implications of the research investigation would appear to provide avenues for improving classroom practice.

The list of propositions P1-P18 (see Table 1) would provide science teachers with a sound basis for planning instruction in genetics. The analysis of concepts and propositions necessary for an understanding of the mechanisms of inheritance revealed many relationships between concepts that are not readily apparent to teachers who have not conducted such an analysis for themselves.

Teachers could enhance the relevance of genetics for lower secondary students by illustrating patterns of inheritance with human examples. Polygenic inheritance should be considered so that students can develop some understanding of the inheritance of skin colour and intelligence. Phenotypic ratios could be de-emphasised as they have little relevance for human genetics; conversely the role played by chance should be emphasised as it is crucial to effective genetic counselling.

The teaching of the monohybrid cross needs to integrate the behaviour of genes and chromosomes. Teachers should emphasise the gamete as a separate and distinctive cell which carries one gene and one chromosome from each pair found in the body cells of the parent, and the separation and reformation of pairs of chromosomes and genes at meiosis and fertilization.

Research has consistently indicated that the majority of Year 10 students are limited to concrete operational thinking. Such students are capable of comprehending the phenomenon of inheritance as it can be developed from concrete experiences such as observations of resemblances within the students' own families. Students' ability to comprehend the underlying mechanisms of inheritance will be limited by the abstract nature of the concepts involved and the extent to which teachers can illustrate the non-perceptible attributes of these concepts.

A surprising aspect of this investigation has been the low level of comprehension of inheritance concepts and propositions amongst Year 10 students in Western Australia. This research outcome raises the issue of the suitability of the mechanism of inheritance being taught as part of the lower secondary science curriculum.

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COMPUTER SIMULATION AND CONCEPT DEVELOPMENT IN STUDENTS OF GENETICS

Judith F. Kinnear, Marjory-Dore Martin and Joseph D. Novak

INTRODUCTION

Most writers contend that students of a scientific discipline should develop an understanding of the conceptual content of that discipline - currently accepted theories, principles and facts - and should also develop an understanding of the processes of scientific reasoning and have facility in their use. Scientific reasoning encompasses a number of cognitive skills that have been variously identified by investigators, and includes the enquiry behaviours of Schwab (1962) and Herron (1971), the enquiry skills in the task analysis of Tamir and Lunetta (1978), the problem-solving processes of Bruner (1960), and the problem-solving behaviours of Mandell (1980). Facility in scientific reasoning includes inter alia the ability to define problems, to design experiments, to make assumptions, to analyse and interpret data, to comprehend causal relationship, to generate hypotheses, and to devise valid strategies for hypothesis testing.

Laboratory-based activities have been seen as a vehicle for the development of skills in scientific reasoning. However, studies (e.g. Stake and Easley, 1978; Humpfreys, 1978; Raghubir, 1979) indicate that biology laboratories often fail to achieve this outcome. Analysis of the activities which form the laboratory component of biology courses reveals a relative paucity of opportunity for the development, practice, and extension of skills in some processes of scientific reasoning, in particular, problem formulation and experimental design (Tamir and Lunetta, 1978).

It is not surprising that laboratory programs have been found to be relatively deficient in providing opportunities for students to generate and/or test hypotheses, and design and actually carry out investigations. It is generally impractical to allow students to carry out self-designed and self- regulated laboratory activities. Difficulties of management in the laboratory, and the constraints of space, time, resources, safe practice and legal resposibilities place obvious limits on the nature and style of laboratory activities. The demands on time arising from the need to cover the content of science courses can lead to the implementation of programs biased towards 'time-efficient' and 'successful' laboratory exercises that are highly prescriptive and reproducible.

For these reasons, students are rarely provided with the opportunity to practise skills in scientific reasoning, such as to design and execute experiements as part of problem-solving or hypothesis-testing procedures, and to modify their experimental design in the light of feedback. The desirability of exposing students to this type of experience is not in question, rather it is the practicability.

Computer simulations, which are free of many of the constraints of 'hands-on' laboratory investigations provide a means whereby students can develop, practise, and refine their skills of scientific reasoning. One area of the

biologocial sciences which is particularly suited to the use of computer simulations is genetics.

This paper deals with student use of a computer simulation as an adjunct to laboratory activities in genetics, and reports on student attitudes to the experience and perceptions of asociated cognitive gains.

METHODS

The Microcomputer

Two 'Apple II' microcomputers with colour monitors were located in the genetics laboratory regularly used by the students involved in the study.

The Computer Simulation

The program used for the investigation was a draft version of 'CATLAB' (Kinnear, 1982). CATLAB is a computer program which simulates the inheritance of coat colour and coat pattern in the domestic cat. The program is 'open-ended' and simply acts as a vehicle for investigation within the context of genetics. It provides genetically valid outcomes from user-selected matings. The problem to be investigated, the starting point, the sequence of investigations and the finishing point can be defined and controlled by the students. Manipulative errors that sometimes swamp and confound laboratory investigations are not encountered and the time constraints of genetics experiments that preclude repeat matings are absent.

The Students

The students taking part in the study were students at Cornell University, N.Y., U.S.A., enrolled in the second-year genetics subject, B10281, during the fall semester, 1981 when two of the authors (J.K. and M-D.M.) were Visiting Fellows at that institution.

Before using the computer simulation the students had carried out extensive experiments over several weeks using Drosophila.

Organisation

Investigations with CATLAB were available on each of seven nominated days over a two week period. Over this period, a total of 25 students voluntarily participated in the study. A photographic display of cat coat colours and patterns was posted in the laboratory and an information sheet on cat phenotypes supplied.

Two types of investigations were available for students, and covered a range of genetics concepts and encompassed different degrees of difficulty.

1. Hypothesis-testing

   e.g. Black coat colour in cats is dominant to grey. Students were required to devise strategies to test the validity of a given hypothesis selected from a pool of twenty-two hypotheses.

2. Problem-solving

e.g. Orange or yellow coat colour occurs in a number of mammals. In hamsters there is a gene with alleles orange and black; this gene is X-linked. In dogs there is a gene with alleles yellow and black; this gene is on an autosome. In cats there is a gene with alleles, orange and black. Use program CATLAB to explore the situation in cats. Is the condition in cats analogous to that in hamsters or that in dogs?
Propose a genetic model consistent with the results you obtain.

Ten different problem situations were available for investigation.

Students were allowed an initial period for familiarisation with the microcomputer and the program. Familiarisation time required was three minutes or less. A tape recorder was left running on 'record' and the student was asked to think aloud. Only one student chose not to work with a tape recorder. An analysis of the transcripts will be the subject of a separate paper. There was no restriction on time available to students and no pressure that a 'correct' answer was required. Students indicated when they had completed an investigation to their own satisfaction or felt they could proceed no further. If students either reach an invalid conclusion about the hypothesis or reached a correct conclusion via genetically unsound arguments, one of the researchers intervened to an extent sufficient to enable students to identify illogical procedures, and so confront their misconceptions.

An evaluation form was voluntarily filled in by students on the completion of the activities. The first part of this form comprised a continuous scale from 0 (LOW) to 5 (HIGH) to measure student attitudes to CATLAB. Students were also asked to respond to the following questions:

- Did the computer simulation using cats extend your understanding of genetic principles? Explain.
- From this experience what value, if any, do you think computer simulations have for a student of genetics?

RESULTS AND DISCUSSION

Time spent by students

The average working time spent on the computer by each of the 25 students participating in the study was 1 hour 40 minutes with a minimum time of 18 minutes by one student and a maximum total time of 4 hours by another.

The majority of students chose to investigate more than one hypothesis. The time distribution on the basis of number of hypotheses/problems investigated is as follows:

Number of Hypotheses/ Problems Investigated	Number of Students	Average Total Computer Time by Each Student (min)
1	6	33
2	11	78
3	4	163
4	4	197

While some students investigated more than one hypothesis in a single sitting others made separate visits for additional investigations. The time distribution on the basis of number of visits to the microcomputer is as follows:

Number of Visits	Number of Students	Total Number of Hypotheses Investigated	Total Number of Problems Investigated	Average Computer Time Per Visit By Each Student (min)
1	17	22	7	61
2	6	11	8	83
3	2	4	4	77

The overall average computer time per student visit was 71 minutes.

As the 25 participating students were volunteers there is no guarantee that they represented an unbiased sample of the total group of B10281 students. From a check of the results of a mid-semester test, it appeared that the sample included students from across the performance range.

Prior experience with computers

Forty-four per cent of the students had previously used a microcomputer. When asked to rate their computer knowledge the distribution of student responses was :

	NIL	LITTLE	MEDIUM	HIGH
N = 25	44%	32%	16%	8%

The attitude of students with no prior experience in computer use may be influenced by the novelty of the situation. However, almost half the sample had had prior experience with the microcomputer, and more than half indicated some knowledge of computers.

Attitudes to the experience

The ratings that students gave to a number of aspects of the program CATLAB are summarised in Figure 1. The student responses have been taken to the closest 0.25 on the scale.

CATLAB appears to provide an intrinsically motivating instructional environment since the students rated it highly in terms of their perceived interest, enjoyment and challenge. This finding is in agreement with a similar study involving genetics students at Melbourne State College. The use of the program also received a high rating for value as a learning experience. This is an important aspect of the findings since enjoyment and interest do not necessarily lead to instructional effectiveness (Malone 1980).

The spread in the perceived difficulty of activities is not surprising. All students were given an initial 'easy' investigation for testing, but those who proceeded to further investigations were given more demanding tasks selected

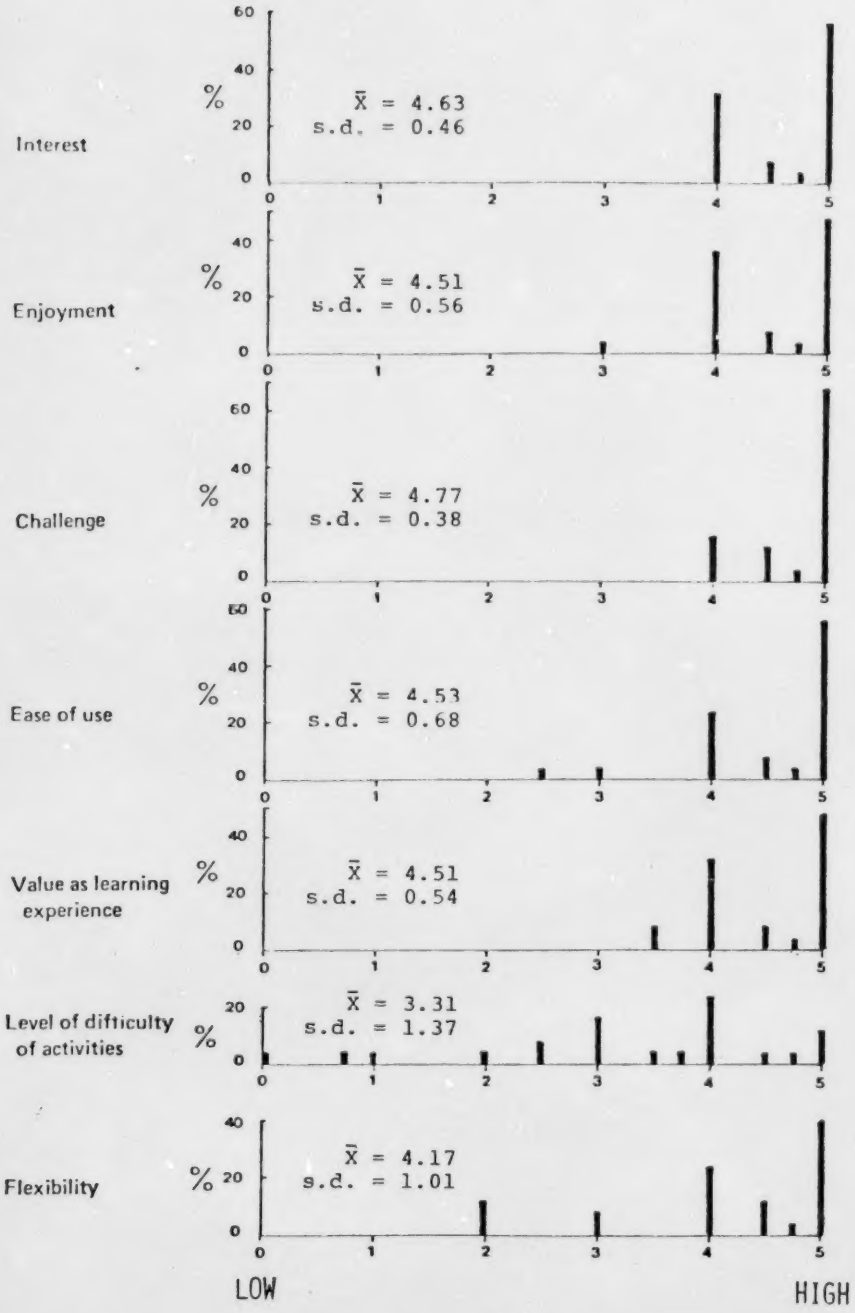

Figure 1. Summary of student responses to a number of aspects of the program CATLAB

on the basis of their performance on the previous task. The responses of two students are excluded from this entry in Figure 1, since their replies were ambivalent. One of these wrote 'They can be very easy or very difficult'.

To the question as to whether the activity had extended their understanding of genetic principles, twenty-four students answered in the affirmative. Six students identified understanding of a particular genetic principle. Seven students identified some aspect of experimental design and ten students indicated an increased understanding of interpretation of experimental results.

Meaningful learning as described by Ausubel (Novak 1976) had occurred with these students. Students appeared to link new information and experiences to existing concepts in their cognitive structure thereby altering the existing concept:

> 'Because the number of cat progeny was lower than with the Drosophila lab and were not always the 'expected' types my Drosophila results became clearer and the need for large numbers of progeny became clearer.'

In addition existing concepts in students cognitive structures were clarified and broadened:

> 'That's the first and only time I have ever come across dominant epistasis. Everything I've every heard of or read in a book, its always been recessive. when you're playing with this you can extend what you have learned.'

> 'It taught me that genetics is not just textbook problems and that you really have to think about it. I never thought to set up a model and to predict what I might get before the crosses were made. I always thought in terms of simply making crosses and looking at them.'

> 'I had to consider the chance involved in genetics and how careful one must be in analysis of data when dealing with small litter sizes.'

One student gave a more general reply:

> 'It gave me an additional way to apply what I have learned in class and in the lab, which is essential to a full understanding of these principles - invaluable opportunity to apply principles.'

The one student who gave a negative response to the question on understanding replied 'not really extended but rather supplemented and refreshed my understanding of genetics.'

The learning gains identified by students covered aspects of both genetic concepts and processes. Concepts are traditionally reinforced and tested by use of problem sets. These problems, however, are parsimonious since they contain a problem statement and only the sufficient and necessary data required for their solution. Use of the CATLAB simulation provides an extension to this type of problem, since the students are provided only with a statement of the problem, and must themselves decide on the relevant data and generate them as part of the problem-solving process.

It has been shown that process skills can be taught through use of appropriate instructional strategies (von Blum 1979, Moshman and Thompson 1981). The present study shows that computer simulations have the potential to provide a setting which facilitates acquisition of competence in scientific reasoning.

All students agreed that computer simulation provides a valuable experience for students of genetics. The forty comments in total made by the students have been classified into categories as shown below.

Value of Computer Simulation	Percentage of Total Responses
Removal of time or other experimental constraints	28
Increase in the variety of problems possible	25
Extension of laboratory work	23
Application of principles	7
Range of student abilities catered for	5
Generation of data for problem solving	5
Familiarisation with computers	2
Non specific	5

Sample student responses include:

> 'For one it allows you to generate progeny very quickly. It also gives the student the opportunity to work with natural populations on an individual litter basis so that they can see that the ratios are not absolutes for individual litters or even for the total amount of progeny. It takes far less time to go through any experiment on the computer than doing the actual experiment, and also to switch ideas if you find you are heading in the wrong direction.'

> 'It gives the students a chance to do all the experiments a geneticist would do in a laboratory over many years in just a few hours on the computer. Invaluable opportunity to apply principles.'

> 'Students must sort out the data instead of having it handed to them in tables. It also allows the student to do his own crosses, instead of relying on only the information given in written problems. It gives the student experience working out problems as a geneticist would.'

> 'It would challenge the more sophisticated student and it would also aid those students having trouble visualizing what is happening in genetics.'

CONCLUSION

Computer simulations in genetics have the potential to complement laboratory activities and to act as an adjunct to the use of traditional sets of problesm. In these roles, simulations such as CATLAB, generate qualitative changes in the learning experiences of students. For example, the simulated breeding experiment may be repeated and strategies modified without regard of the time and management constraints associated with actual laboratory experimentation; problem-solving may involve active data generation, in contrast to the style of textbook problems.

This study showed that students reported a favourable attitude to CATLAB and that their use of the program lead to meaningful learning. The cognitive gains made by the student group encompassed both genetic concepts and processes. The scope for use of computer simulations as an adjunct to, or in some cases even replacement of traditional activities, and for an analysis of their impact is considerable.

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SCIENCE RELATED ATTITUDES AMONGST VICTORIAN CATHOLIC PRIMARY SCHOOL TEACHERS

Peter T. White

INTRODUCTION

A limited number of studies of the implementation of the Victorian primary school Science programme over the last decade have been undertaken. Symington and Hawkins (1972) surveyed 147 teachers in suburban schools near Toorak Teachers' College. They concluded that '... a secondary school background does not appear to have any effect upon the time the teacher devotes to science, or the extent that class topics arise from the teacher's own background' (p. 4).

In a similar study of both State and non-State primary school teachers from the Geelong and Corio inspectorates of Victoria, Henry (1977) reported a decline in the amount of science being taught.

Colbourne and Brockley (1980) surveyed a sample of teachers who subscribed to the Bendigo C.A.E. weekly Science Programmes and Resources Units in 1979. However, care should be exercised when considering their claim such as 'the downward trend (in amount of science being taught) found by Henry (1977) has been reversed'.

White, Raun and Butts (1967) had found a lack of interest in Science by teachers in the United States to be a major contributing factor to the limited occurrence of Science in the elementary school curriculum. Conant (1974) reported that in Portland, Oregon, the average time spent on Science in elementary schools was as low as two minutes per day. Spooner and Simpson (1979) have argued that 'teachers who "like" Science or "feel it is as important" find time to include this subject in their busy schedules' (p. 415).

The proposal that an attitude towards Science is important in whether or not teachers include Science in the curriculum would then appear worthy of consideration. A measurement of scientific attitude was therefore sought.

THE STUDY

The current study, as well as replicating aspects of the three previous Victorian studies, introduces a measurement of Scientific Attitude. On this occasion, the target is the Victorian Catholic primary school system, a system which in 1981 provided for the education of nearly 100,000 students. This represents over 20% of the number of students who were enrolled in primary schools in Victoria (ABS; 1982).

The Instrument

In addition to a series of items which were similar to those of the previous studies, questions to determine teachers' familiarity with a range of 'standard' Science curriculum packages were included in the questionnaire, as well as a twenty item attitude inventory in the form of a Likert-type scale and a final open section for any other comments.

The Attitude Scale

In addition to those measurements of scientific attitude referred to above, a range of other instruments was examined, but ultimately the scale chosen for this study was a modified form of that devised by Spooner and Simpson (1979). This is a measure of attitude towards Science rather than a measure of the scientific attitude.

The instrument was based on the 'Surveys of Opinions toward Elementary School Science Scale', which had been developed by 'an expert panel' of Science educators and educational research specialists. A twenty item Likert-type scale was constructed with the statements focusing on common attitudes of teachers towards Science as well as the important goals and characteristics of the Science Curriculum Improvement Study (1976), and other features of method and goals as seen appropriate by the 'expert panel'. Certain words and expressions were changed to suit the Australian context of the present study.

The scale allowed for five possible responses in each case ('Strongly Agree', 'Agree', 'Undecided', 'Disagree', 'Strongly Disagree') with scores of 5, 4, 3, 2 or 1 respectively being given for the responses. In the cases of items 1, 2, 4, 10 and 18, these scores were reversed. The maximum score on the scale would then be 100 and the minimum 20. A score of 60 was taken as indicating neutral feelings; below 40 indicating negative attitude, and above 80 indicating positive attitude (Spooner and Simpson, 1979, 418).

The attitude scale was administered as an integral part of the total questionnaire to all of the full-time teachers in a random sample of 33 Victorian Catholic Primary Schools.

RESULTS AND DISCUSSION

272 completed questionnaires were returned. This represents 66% of the full-time teachers in the 33 selected schools.

I A brief comment on the comparison of findings with those of the previous studies -

At this stage of analysis, the current study would tend to indicate that compared with the state system, the Catholic schools appear to have a slightly higher proportion of less experienced teachers, and a very much lower proportion of male teachers working in them. An increase in the secondary school science background of teachers, as well as the science component of teacher education courses and attendance at science related in-service programmes over the decade has been detected, but this has not been translated to more science being taught in the school. On the contrary, a progressive decrease in the average amount of class time spent on science has been observed. These findings will be reported in some detail elsewhere.

II The Attitude Scale

The lowest score in the sample was 60, the median was 74, the mean was 75.5 and the highest score, a very high 96. Twenty-five percent of respondents had scores of 80 or above, which Spooner and Simpson have described as representing very positive attitudes to Science. Whilst the mean of 75.5 indicates a positive attitude towards science, it is lower than the 79.8 found by Spooner and Simpson for their American sample's pre-test (1979, 418). One could speculate about the reasons for these high attitude scores, and the minor discrepancy between the American and the Australian samples, but such speculation would fall outside the scope of this paper.

In order to achieve an estimation of the internal consistency or reliability of the twenty item aggregate, Cronbach's Alpha statistic was calculated. It yielded a coefficient of 0.8, which indicates a reliable instrument for the measurement of teachers' attitudes to Science. This compares favourably with the 0.69 and 0.72 respectively for Spooner and Simpson's pre and post tests (1979, 418).

A factor analysis was carried out on the attitude scale data. Five, four, three and two factor analyses were attempted, and in each case, two factors had eigen values greater than 1.00. The two factor solution produced eigen values of 4.36 and 1.39 respectively.

The first factor (Factor 1) accounted for 76% of the variance and involved major contributions from eleven items (2, 3, 5, 9, 12, 13, 15, 16, 18, 19, 20), whilst the second factor (Factor 2) accounted for 24% of the variance and was characterised by five items (7, 8, 10, 11, 14). The major items which contributed to Factor 1 were:

Item 2 Primary science teaching should (not) be based on a text book approach.

Item 3 Primary students should have had many 'hand-on' experiences in science such as field trips, experiments, etc.

Item 5 Multiple references are more desirable than a single text in teaching science.

Item 9 Student understanding of the processes of science, such as measuring, clarifying, and observing, is as important as knowing the facts and concepts of science.

Item 12 The science teacher should be a good guide or facilitator of learning - not a teller.

Item 13 Student interaction and exchange of science ideas are an important part of learning.

Item 15 Field trips should be an important part of primary science teaching.

Item 16 Developing favourable student attitudes towards science is an important part of science instruction.

Item 18 Students should (not) know exactly what results they are going to get before doing science experiments.

Item 19 Open-ended teacher-directed questions are very appropriate for science teaching.

Item 20 Primary science should correlate well with other subject areas such as reading, maths, art, etc.

Factor 1 would appear to be an enquiry/involvement-orientated open approach to curriculum, or a concurrence with the aims of the school Science course, and so will be referred to as the 'Concurrence With the Course Objectives Factor.'

The five items which characterised Factor 2 were:

Item 7 I enjoy teaching primary science.

Item 8 My undergraduate college training in science has been of much value in teaching primary science.

Item 10 My background is (not) inadequate for effective primary science teaching.

Item 11 I feel comfortable using living organisms in the classroom.

Item 14 I feel comfortable using science equipment.

Thus factor 2 would appear to relate to teachers' backgrounds and confidence in teaching science and will be named the 'Teacher Background/Confidence Factor'.

Factors 1 and 2 yielded alpha values of 0.82 and 0.70 respectively, thus confirming the reliability of the scales. In isolating the Concurrence with the Course Objectives Factor, as well as the Teacher Background/Confidence Factor in a teacher's attitude to Science, the attitude inventory supports the arguments which had been proposed by the Primary Science Curriculum Committee in support of the association of a comprehensive in-service teacher education programme with the introduction of the Science course.

The attitude scores were collapsed into three groups which were as close to being numerically equal as possible. The bottom 31.6% formed the low attitude group, the next 34.2% comprised the middle group, and the upper 33.2% made the high attitude group. These collapsed scales were cross-tabulated with a range of other variables.

The Chi square statistics were calculated. They indicated a significant negative relationship between the collapsed attitude scores and teachers' experience ($\chi^2 = 11.90$, df = 4, $p < 0.02$). Positive relationships were found between the collapsed attitude scores and Science studies in Year 12 of schooling ($\chi^2 = 7.84$, df = 4, $0.1 > p > 0.05$, NS), the amount of teacher in-service attendance ($\chi^2 = 9.82$, df = 4, $p < 0.05$), and the teachers' familiarity with, and use of, the Victorian Education Department's science courses ($\chi^2 = 18.87$, df = 8. $p < 0.02$).

CONCLUSION

This study is preliminary in nature, and the instrument will require some modification to reduce its length and to further increase the reliability of the attitude scale. None-the-less, in addition to replicating some important aspects of previous studies, and introducing a measurement of primary school teachers' science related attitudes, it does provide valuable data prior to the introduction of the new course guides. When used in conjunction with the findings of a similar survey which is to be conducted in 1983, these data will help to assess the impact of the introductory phase of the course in Victorian Schools.

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THE USE OF COMMONALITY ANALYSIS IN THE ANALYSIS OF TEACHERS' ATTITUDES AND PRACTICE TOWARDS PRIMARY SCIENCE

Peter Codd

INTRODUCTION

The commonality analyses presented here were part of a study which explored the attitudes and practices of teachers in Catholic primary schools in Sydney towards primary science education. It aimed to investigate how much science these teachers taught, the kind of science they taught, and the personal and environmental factors which influenced the amount and kind of science they organised for their pupils.

A questionaire was designed and tried out in November, 1980. A revised version of this questionaire was distributed in September, 1981. The responses of 421 teachers from 71 schools were returned and analysed. The response rates were 94% for schools and 77% for teachers.

This paper discusses one of the regression methods used in the study, the systematic decomposition of variance, also known as commonality analysis.

Commonality Analysis

Commonality analysis is a method of systematic partitioning of variance into unique and joint effects (Madaus, Airasian and Kellaghan, 1980, 70-71; Tatsuoka, 1973, 306-309; Beaton, 1974; Mood, 1971). It seeks to partition explainable variance in a dependent variable into the portions attributable to each independent variable and to all combinations of independent variables in order that we may better understand the interactions of predictors in estimating the criteria (Beaton, 1974, 63). One advantage of commonality analysis over other regression methods is that the partitioning of the variance does not depend on the order in which the variables are entered. It also allows the overlap between the independent variables in explaining variance in the dependent variable to be expressed (Madaus et al., 1980, 71).

THIS STUDY AND ITS ANALYSIS

Two criteria, or dependent variables, were used. They were:

1. The average time per week that teachers devoted to science in their classes, (SCITIME), and

2. The average time per week in which pupils were actively involved in doing science with simple materials (ACTIME).

Blocks of independent variables, rather than single variables, were used. There were several reasons for grouping the independent variables into blocks. One was an attempt to overcome the problem of multi-collinearity by clustering highly-correlated variables into a single block. Another was to reduce the number of higher order commonalities (Nie and Hull, 1975, 340; Madaus et al., 1980, 67-69).

Three blocks of independent variables were used. These were:

1 Student-centred teaching styles (SC) (DeLuca and Downs, 1979). This block was concerned with student activity, inquiry, and small group work. The alpha coefficient of reliability for this block was 0.86.

2 The personal system, (PERSONAL), (Moos, 1979, 11). This was a set of five scales concerned with teachers' attitudes towards science and science teaching, their perception of the importance of science in the primary curriculum, and their confidence in their ability to teach science. (Alpha = 0.87).

3 The relationship dimension of the environmental system, (RELATIONSHIPS), (Moos, 1979, 14). This was a set of four scales concerned with the support and encouragement for science given to teachers, the extent to which the science program was planned, the availability of resources for teaching science and the priority given to the scheduling of science. (Alpha = 0.76).

In the commonality analysis, the squared multiple correlation (R^2) is broken down into elements which are assigned to each individual predictor and to each possible combination of predictors. Thus, the commonality of the PERSONAL and RELATIONSHIPS blocks can be expressed as R^2 of the two blocks combined, minus the unique variance explained by each of these blocks.

The term 'unique' is used to mean that the variance associated with all other blocks, taken singly or in common, is controlled for. Thus, the amount of variance in a criterion uniquely associated with a single block is called a 'unique effect'.

Commonality Analysis for the Criterion, SCITIME

The three blocks of independent variables, student centred teaching style (SC), the PERSONAL block and the RELATIONSHIPS block, accounted for 20 per cent of the variance in the criterion, SCITIME, the average time per week that teachers devoted to science. Table 1 shows the unique and common effects of each block in terms of percentage of total variance in the criterion.

TABLE 1 - Partitioning of the Variance in the Criterion SCITIME (N = 421)

Predictor	% of total variance
UNIQUE EFFECTS	
SC	0.58
Personal	0.93
Relationships	8.31
TOTAL UNIQUE EFFECTS	9.82
COMMONALITIES	
SC and Personal	0.40
SC and Relationships	0.27
Personal and Relationships	6.90
SC and Personal and Relationships	2.63
TOTAL COMMONALITIES	10.24
TOTAL EXPLAINED VARIANCE	20.06

It can be seen from Table 1 that the RELATIONSHIPS block accounted for the greatest amount of unique variance while commonalities accounted for most of the rest of the explained variance.

This commonality analysis has shown that the variable which accounted for the greatest amount of unique variance in SCITIME was the RELATIONSHIPS block. This block was concerned with the extent to which teachers felt involved with the science programme and the teaching of science at their school and the extent to which they tended to support and help one another in the teaching of science and to be supported and helped. The unique contribution of the other two blocks, student-centred teaching style (SC) and the PERSONAL system, was quite small.

The largest of the commonalities was that between the PERSONAL and RELATIONSHIPS blocks. Thus, the influence of the personal system cannot be separated from the relationship dimension of the environmental system.

Commonality Analysis for the Criterion, ACTIME

The blocks of independent variables were the same as those used in the previous analysis, namely, student-centred teaching style (SC), the personal system (PERSONAL) and the relationship dimension of the environmental system (RELATIONSHIPS). The criterion was ACTIME, the average time per week in which pupils were actively involved in doing science with simple materials. These three blocks of variables accounted for 18 per cent of the variance in the criterion. The partitioning of this variance is shown in Table 2.

TABLE 2 - Partitioning of the Variance in the Criterion ACTIME (N = 421)

Predictor	% of total variance
UNIQUE EFFECTS	
SC	4.15
Personal	2.36
Relationships	3.40
TOTAL UNIQUE EFFECTS	9.91
COMMONALITIES	
SC and Personal	0.86
SC and Relationships	0.69
Personal and Relationships	3.22
SC and Personal and Relationships	3.20
TOTAL COMMONALITIES	7.97
TOTAL EXPLAINED VARIANCE	17.88

All three blocks of independent variables make a unique contribution to the variance in ACTIME. That due to student-centred teaching style is the largest but those due to the relationship dimension of the environmental system and to the personal system are also important.

DISCUSSION

The partitioning of the variance of SCITIME, the average time per week devoted to science, showed that the RELATIONSHIPS block accounted for most of the unique variance. The other two blocks accounted for very little of the unique variance.

These results indicate that programs to increase the amount of time devoted to science in primary classes should concentrate on school staffs rather than on individual teachers. The variables in the RELATIONSHIPS block show the area these programs should emphasise. Such programs should aim to increase the support and encouragement given to science among the staff; should assist the staff to plan and implement the school's science program; should teach the staff how to obtain and organise the materials needed to teach science, and should lead the staff to appreciate the value of science in the primary curriculum so that they will give a higher priority to the scheduling of science.

A feature of recent primary science curricula in Australia has been the emphasis placed on an activity-based approach (Pearce, 1981, 34). Crocker (1979, 55) has shown that there is considerable teacher opposition to such an approach. The results of the partitioning of the variance of ACTIME indicate that programs designed to assist teachers to implement such an activity-based science curriculum in their classrooms should have a multi-dimensional approach. Programs will have to involve both individual teachers and school staffs. They will have to convince individual teachers of the advantages of a student-centred teaching style with its emphasis on student acitivity, inquiry and small group work. They will have to be structured carefully to build up teachers' personal attitudes to science teaching, particularly their self-confidence in their ability to teach science in a student-centred style. It is most important that these programs do all they can to ensure that teachers' first attempts to teach science in this way are successful and so build up these personal attitudes. These programs should also build up the relationship dimension of the psycho-social environment of the staff, as outlined above.

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MEDICAL STUDENTS' PERCEPTION OF SCIENCE

Margaret Brumby

INTRODUCTION

In the last few years at ASERA two aspects of secondary school science education have been highlighted. One is the clarification of goals in science teaching. Fensham (1980) described new objectives for science teaching; Karplus (1980) described teaching for the development of reasoning. The other is the growing number of reports about students' understanding of science learnt at school. Almost without exception these reports contain rather disquieting observations about students' misunderstandings of basic scientific concepts. Osborne (1980) coined the term 'children's science', which he showed could be very different from the 'scientists' science' of textbooks and school curricula. Gunstone and White (1980) reported conflict between tertiary physics students' expectations of events ('learned science'), and their subsequent explanations of observed events ('real world science'). Using unfamiliar problems set in the real-world rather than traditional textbook knowledge, I have found that the majority of biology students entering tertiary studies are unable to recognize problems based on the concept of natural selection (Brumby 1981), or to provide scientific reasoning to identify if an unfamiliar object was alive, dead or non-living (Brumby 1982). Other studies with tertiary students (Baird & White 1982; West, Fensham and Garrard, 1981) show that basic genetics and chemistry concepts, although studied at school, have not been clearly understood.

Where does the problem arise? Novak (1976) attributes much to school teaching methods which still encourage 'right' answers, and to exams which primarily assess factual knowledge. These result in students memorising or rote-learning their work, rather than actively integrating new material with their existing knowledge, and applying it to relevant problems. This latter active form of learning has been called meaningful-learning by Ausubel (1968). Despite our growing concern about the implications of these results of science education research, students continue to spend hundreds of hours studying and 'doing' Science at school.

Due to tertiary selection procedures, some of the most successful secondary science students enter tertiary medical school. While working with the first-year medical students at Monash in 1981 on their understanding of basic biological concepts, I became aware of a curious gap in their explanations. It was not so much what they did say, but rather what they <u>did not</u> say, in attempting to solve unfamiliar biological problems. This paper presents these findings.

METHODS

Four divergent problems were given to the students during the year, in different formats:

1. Mars Problem

> If you were on the first manned space-ship to land on Mars, what evidence would you look for to determine whether living organisms exist there?

(Written problem, written explanation, March, replacing normal lecture, n=150)

2. Rock Problem

> If you were walking along the beach, and came across this, how would you go about finding out if it is alive, if it was once alive but is now dead, or if it has never been alive, i.e., non-living?

(Oral problem with greyish-green rock, student taped 'thinking aloud' and subsequently transcribed, individual interviews March-April, n=32)

3. Nuclear Problem

> Recently there occurred a nuclear accident at the Three-mile Island nuclear plant, in America, and a considerable amount of radioactive material escaped into the surrounding environment.
>
> If you were a doctor working at a nearby hospital, and were asked to join an expert committee to monitor the effects of this leak, what ideas would you put forward?

(Oral problem, individual written explanation, September, at beginning of normal lecture, n=121)

4 Natural Selection Problem

> Explain briefly, but clearly, why a member of the medical profession should undertstand the process of natural selection. Give two examples of medical importance.
> (10 marks, 11 lines)

(End-of-year Biology exam equestion, n=160, written by course lecturer)

Students explanations were analysed and categories subsequently formed.

RESULTS

The full categories of these problems are contained in Appendix 1. The absence of scientific experimentation or reasoning was strikingly obvious in problems at the beginning of the year.

1. In the Mars Problem, students focused on one answer, so results in Appendix 1 are percentages of students who answered in that category. Eleven students (7%) designed experiments which could reveal the presence of life:

> 'Whether the life processes that we know of, e.g., respirations or photosynthesis occur there. One approach would be to incubate a soil sample, labelled with radioactive nutrients and see whether radioactive CO_2 was evolved'.

Eight students (5%) thought to look for DNA or a self-replicating molecule. Four students (2%) suggested looking for an energy source, or a means of harnessing solar energy. The majority of students looked for organisms and/or life-supporting constituents of the biosphere (e.g., oxygen, water).

2. In the Rock Problem 5 students (16%) made hypotheses, planned tests, and stated what conclusions could be drawn from results:

> 'I'd study its microscopic constitution to see if it was cell-like. If there were cells which were functioning; e.g., were motile, then I would assume that it is alive; if there were cells but no movement then it's dead; if it was crystalline in structure then it's non-living.

Six students attempted to plan tests but did not retain all 3 questions and only distinguished living:non-living. The remainder (two-thirds) of students suggested various observations, frequently based on the traditional seven characteristics of multi-cellular living organisms (growth, reproduction, irritability, nutrition, excretion, breathing, locomotion) but drew no conclusions:

> 'I'd take a sample and look for cells, immerse it in water and see if it changed'.

Only one student thought to mention DNA, and raised an intriguing question:

> 'I'd take it to a lab. and test for the presence of DNA, or dead DNA. (I haven't done Biology so I'm not sure about this.) Test for carbon - organic compounds are the basic compounds of life - and hydrogen'.

3. The Nuclear problem was given after students had completed studies on Molecular and Cellular Biology and Genetics. A total of 459 ideas were obtained from 121 students. Of these only 10 students suggested any experimentation with animals with a shorter generation time, using the known level of radioactivity to test for possible longer-term effects. Ten students thought to study cells (or chromosomes) taken from people in the affected area. Twelve suggested long-term monitoring of several human generations which implied observations of well over one hundred years. The great majority of explanations were in terms of 'measurement' of radiation (without conclusions) or 'monitoring effects' (without specifying what particular effects would signify).

4. The Natural Selection Problem was the final question in one of two end-of-year Biology examination papers. Darwinian evolution had been a major component of Term 1 course, preceding Genetics. One-third of students satisfactorily applied the concept of natural selection to medicine, either in terms of the frequence of genetic diseases, or by pointing out the role of medicine in overcoming negative selection pressure.

Nearly one-third focused on the environment, or geographical differences around the world, revealing continued misunderstanding of a selective process described elsewhere (Brumby 1981):

> 'Nat. sel. was an essential factor in the evolution of Mankind. Since physicians treat Man, they should understand the process that resulted in his present anatomy and behaviour. Nat. sel. is a continual process and is evident today, e.g., in the Cepea snail. It may prove to be of importance to Man's well-being in this biosphere. For e.g., with excessive use of antibiotics, tests show that strains of bacteria may become immune to its effects. Nat. sel. may play an important role in the adaption of Man to our changing environment (e.g., pollution)'.

Another wrote:

> 'Nat. sel. can give us an insight into why and how various diseases or resistance to diseases or mutations or lack of mutations exist in, say certain geographical areas. Ignorance will be dispelled with and cures can be researched for the betterment of mankind's health, e.g. sickle cell anaemia ...'

Evidence given in support of evolution in lectures included a comparison of homologous structures. Several students implied a master-mind role for natural selection:

> 'Nat. sel. gives an insight into why certain species of animals are present today and why some have become extinct. It is important to the medical profession because the human body is a gradual development guided by nat. sel., extinction of unuseful parts, amplification of useful parts and by understanding these we are closer to understanding why certain organs situated in certain parts of the body and why organs have their structures e.g., (a) heart (student detailed fish -- mammal heart structure) (b) elaboration of brain (detailed (i) -- (vii) levels)'.

Analysis of specific examples of medical importance showed that 25% of all examples (which represented more than half of all students, since not all students answered this part of the question) was accounted for by one genetic disease, sickle cell anaemia. Within this group only 16% clearly explained the allele for sickling and the significance of the heterozygous and homozygous genotypes.

DISCUSSSION

The most striking finding in these results is the absence of scientific reasoning by these students, the most successful students of secondary school science (with or without biology). If one accepts Popper's notion of refutability by observation (Magee 1973), then this absence of scientific reasoning has considerable significance in analysing these students' perception of science. Science is seen by them as a body of absolute, culture-free knowledge, most of which is recorded in books, or yet to be discovered by experts. Their task as students is to learn it, so they will increasingly 'know' all the answers. Hence they are becoming increasingly skilled at rote-learning, or passively memorising all the content of their lectures. When confronted with an unfamiliar problem, which by definition requires transfer of a concept learnt in one context, to a different context, many students have difficulty and do not reach a possible solution. This is shown most clearly by the difficulty the majority of students had in applying

the concept of natural selection to medicine. Only about one third clearly related it to the frequency of genetic diseases. Instead of transferring their understanding of a selective process to a medical context, many students faithfully reproduced the content of their evolution lectures (which I had attended). Very few students indeed applied their understanding of cells and chromosomes in the Nuclear problem.

In referring to genetic disease, the high frequency use of the West African genetic disease, sickle cell trait, also illustrates, I believe, this difficulty in application. Very few students mentioned genetic diseases which are significant in the Australian community, such as thalassemia, Down's syndrome or galactosemia. It could be argued that the question did not specify an Australian context, nor did it indicate whether 'medical importance' should be considered in terms of mortality rates, incidence, or in terms of health care costs, such as the pku monitoring system. Further it could be argued that there was insufficient space allowed for adequate explanations. I do not believe however that student's answers reflect these criticisms. Despite the hours they have obediently spent in science laboratories, both secondary and tertiary, and in dilgently 'learning' copious lecture and textbook notes, many of these students have not yet developed a wider view of science as a method of reasoning and studying the unknown. They appear to regard science just as an ever increasing stockpile of scientific knowledge.

Why have these students acquired and retained this emphasis on knowledge? I believe the method of assessment in science subjects has a considerable influence in encouraging both rote-learning and accumulating detailed factual 'bits' of knowledge. These students are the most successful products of an intensely competitive secondary system, where success is measured in marks gained from choosing right answers in mainly multiple-choice exams. To them the rules of assessment (and therefore success) have not significantly changed in this first year of tertiary education. They are still competitive and success-orientated, even if the medical course is not.

As a transition year between school and the later medical studies, the first year could be an excellent opportunity to undo the emphasis and damage wrought by the knowledge-orientated secondary school science subjects. It could encourage vigorous questioning and critical thinking of accepting uncertainty and offering alternative solutions to scientific problems. With increasingly crowded curricula there is a danger that there will be less time for students to ask their questions, in favour of receiving answers to questions they have not yet asked. Remember the one student, tackling the Rock Problem, who said thoughtfully: 'I'd take it to a lab, and test it for DNA, or dead DNA ...' Dead DNA? The complex details of double helixes, base pairs, euchromatin, etc. had not answered this simple question. Yet it is only by hearing their questions, and by reading their answers, that their understanding, and lack of precision in scientific language is found.

Of more direct concern (if this interpretation of these student's consistent performance on problems and exam questions is accepted) then one of the World Health Organization's goals in medical education (Guilbert 1977) 'to train the future physician not in (scientific) academic specialities, but to ensure that the student is able to detect any violation of basic scientific principles in his (/her) practice', has scarcely begun to be achieved. And for all those science students who did not 'win the HSC prize' of entry into medicine, what are the implications of these findings for their understanding of scientific principles, concepts and reasoning?

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APPENDIX 1. Categories of Responses in each problem

1. MARS PROBLEM ANALYSIS	% Students
Organisms, cells and movement	24%
DNA, self-reproducing	5%
Biosphere (O_2, water)	15%
Energy source/harnessing	2%
Orgs. + biosphere	35%
Tests for processes of change	7%
Signs of intelligence	7%
No Answer	5%
	100%

2. ROCK PROBLEM ANALYSIS	No. of ideas
(a) Content of answers	
Appearance - gross	14
- internal	6
- cells	9
Seven characteristics	21
Do tests - DNA, water, respiration	11
Decomposition	1
Texts/experts/comparisons	17
	79

(b) Method of reasoning	No. of students
3 Hypotheses	5
Incomplete	6
'Spectators'	21
	32

3. NUCLEAR PROBLEM ANALYSIS	No. of ideas
(i) Measure level of radiation - - - - - - - - - - - - - -	142
air	53
water	28
soil/plants	9
food	20
body	22
relate area: people	10

(ii) Action		94
shut down/seal off area	9	
evacuate if necessary	24	
study safety factors	17	
ask nuclear expert	3	
experiments with shorter gen.	10	
get off committee	3	
people:		
affected/sterilize	13	
educate for effects	8	
care for/counsel	5	
study those not sick	2	
(iii) Study effects		223
plants/nat. env.	34	
birds/animals	22	
buildings	3	
people	27	
monitor births/infertility	34	
monitor cancer	24	
monitor deaths	7	
monitor abnormal diseases	4	
monitor psychological effects	3	
compare health - non-affected	19	
short and long-term effects (vague)	21	
short - radiation sickness	3	
long - future generations	12	
study cells, chromosomes	10	
Total ideas		459

4. NATURAL SELECTION PROBLEM ANALYSIS

(a) Application to medical practice	% students
Combating nat. selection pressure/freq. of genetic disease	34%
Effect of environment (inc. adaptation)/populations different around world	31%
Evolution of homologous structures/?culture, behaviour	15%
Ethical problems, eugenics	6%
Baterial/parasitic evolution	14%
	100%

(b) Specific examples of medical importance	% examples
Genetic diseases (gen. & specific)/counselling	29%
Sickle cell anaemia (42%), & malaria (42%), allele (16%)	25%
Cancer	2%
Genetic engineering	5%
Evolution of homologous structures (gen. & specific)	12%
Drug-resistant bacteria (gen. & specific)	21%
DDT & insecticides	6%
	100%

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A STUDY OF THE SCIENTIFIC ATTITUDE OF SCIENCE EDUCATORS WHO STUDY SCIENTIFIC ATTITUDES

C.F. Gauld

INTRODUCTION

Over the past decade there has been a renewed emphasis on the importance of developing scientific attitudes in science pupils and most modern science curricula have expressed this emphasis by listing such things as objectivity, scepticism and open-mindedness as personal characteristics which pupils should develop in the science classroom.

The importance of the scientific attitude in science education is based, in part, on the claim that the behaviour of scientists (and of scholars in general) is substantially motivated by this attitude and a large amount of research in the science education literature has been devoted to deriving a conception of the scientific attitude from the writings of scientists, philosophers of science and science educators (Gauld & Hukins, 1980).

At the heart of this notion of the scientific attitude seems to be a particular view of evidence and how it should be treated in making decisions. Evidence should be collected and evaluated impartially so that idiosyncratic prejudices do not distort it. Relevant information is actively sought and no source of such information is rejected before it is fully evaluated. All relevant information so collected is carefully weighed before a decision is made. No idea, conclusion, decision or solution is accepted or rejected just because a particular person makes a claim but it is treated sceptically and critically until its soundness can be judged according to the weight of evidence which is relevant to it. A person who is willing to follow such a procedure (and who regularly does so) is said by science educators to be motivated by the scientific attitude. However there is consistent evidence that scientists do not reflect the characteristics outlined above and consequently are not motivated by the scientific attitude promoted in the science education literature (Gauld, 1982).

Since there is apparently a discrepancy between the attitude scientists affirm verbally and their behaviour in the research context and since the scientific attitude is generally seen by science educators as motivating the work of all scholars, one would expect to find the same discrepancy within the work of science educators who write about the scientific attitude. The purpose of this study is to investigate the way this group of science educators handle information and evidence which is relevant to their field and to see how well this conforms to their characterisation of the scientific attitude.

DESCRIPTION OF THE DATA

When the results of a research project are published, information about ideas and evidence which have been taken into account are usually found in citations occurring throughout the publication. This feature of the publication provides the appropriate opportunity for acknowledging ideas which contribute to or support the views expressed as well as those with which the author may

disagree. Through a study of citation behaviour it should be possible to investigate how science educators who study the scientific attitude treat the relevant pool of ideas and evidence.

The source material used in this study were fifty-nine papers dealing substantially with the general scientific attitude (rather than concentrating on specific components such as curiosity, dogmatism, or superstition) and which were published in science education journals before 1980. The articles were gathered through the use of abstracting service indexes, journal indexes, references in theses and in papers already obtained and represent as complete a collection of such articles as possible. The first was published in 1926 and the last in 1978. The frequency distribution by date is shown shown in the first two columns of Table 1.

TABLE 1 - Distribution by Date of Source Articles and Potential Citations

Date Range	Group			
	Source Articles	PSS	GSA	CDS
1910-1919	0	0	0	1
1920-1929	1	0	1	2
1930-1939	13	1	6	16
1940-1949	7	2	2	2
1950-1959	9	3	3	0
1960-1969	12	13	3	6
1970-1979	17	35	5	9
TOTAL	59	54	20	36

This study then is of the collective scientific attitude of the authors of these fifty-nine papers and, in particular, of the way they handle evidence which is relevant to the nature of the scientific attitude and to its role in science education.

Citation Patterns in the Source Articles

The fifty-nine source articles all together produced 426 citations to both books and articles and the subject content of these citations is shown in Table 2.

Each citation was further classified in two ways. It was identified as
(a) substantial or perfunctory according to whether or not it forms a substantial part of the case being made in the source paper and
(b) favourable or unfavourable according to whether the information referred to was accepted or rejected by the author of the source article.

Of the 246 citations arising from the fifty-nine source articles exactly half were considered to be perfunctory. They represent comments made in passing to other work and embody background information about which no critical comment is passed. Many of these citations are found in the introductory or concluding sections of the papers.

TABLE 2 - Subject Content Distribution of Citations

	Subject Area	Number of Citations	%
1.	Material substantially devoted to the General Scientific Attitude		
	(a) Articles in Science Education Journals*	54	12.7
	(b) Articles in other journals	11	2.6
	(c) Books and dissertation	29	6.8
2.	Material partially devoted to the General Scientific Attitude	20	4.7
3.	Material devoted specifically to Curiosity, Dogmatism or Superstition	3	0.7
4.	General Science Education	109	25.6
5.	General Science	17	4.0
6.	History and Philosophy of Science	45	10.6
7.	Sociology and Psychology of Science	10	2.3
8.	Psychology of Attitudes	20	4.7
9.	General Subject Areas (Education, Philosophy, Psychology, Sociology)	67	15.7
10.	Research Methods	41	9.6
	TOTAL	426	100.0

*This group is a subset of the source articles themselves

The remaining 213 citations are those which refer to work which is substantially related to the arguments presented in the source papers. Almost all of these are dealt with favourably and in only 16 cases is work cited which the author of the source article rejects in anything but a perfunctory manner. Thus, in only 16 cases out of 426 is serious consideration given to alternative positions to those of the authors of the source articles. These 16 substantial and unfavourable citations occur in only four of the fifty-nine source articles (in fact, 12 are located in only two papers). In three of these four articles an area of substantial disagreement is the nature of the scientific attitude (10 citations) while in two papers it is the suitability of different scales for measuring scientific attitudes (6 citations).

The above analysis deals only with the citations arising from the source articles and the conclusions one draws also depend, to a large extent, on the evidence that is actually available for citation. If negative evidence does not exist or is so recent that one could not expect it to be frequently cited before 1979 then the above patterns are completely understandable and of little significance for the present task.

The Domain of Potential Citation

Three groups of material published before 1980 and relevant to the discussion of the general scientific attitude were identified by much the same procedure that was used to identify the original group of source articles.

The first group (Group PSS) consisted of 54 articles or books concerned with the psychology and sociology of science in which research into the personalities or behaviour of scientists and the scientific ethos (or the norms of science) were discussed.

In the second group (Group GSA) were 20 articles dealing substantially with the general scientific attitude but published in journals other than those concerned directly with science education.

The third group (Group CDS) was made up of 36 journal articles each dealing with either curiosity, dogmatism or superstition in the context of education. Curiosity, open-mindedness and lack of superstition are often identified as components of the scientific attitude. The frequency distribution by date of these groups of publications is shown in Table 1.

Each of the papers in the above three groups is a potential citation by the original collection of source articles and for each of these groups of papers it is possible to define a domain of potential citation with respect to the original set of source articles. Material published after a particular source article was submitted for publication cannot be cited by that source article and it was assumed that source articles were submitted one year before their publication. Thus a source article published in 1970 could only refer to articles published in 1969 or before.

With this restriction in mind the total possible number of citations to articles in Group PSS which could occur in the source articles is 828. For our set of source articles this is thus the size of the domain of potential citation for Group PSS. However, the number of actual citations to this group of articles was only 10 (a 'citation rate' of 1.2%) and, of these, eight appeared in one source paper. This information and similar data for the other two groups (GSA and CDS) are shown in Table 3 together with data about 'self-citation' (that is, when articles in a particular group cite other articles in the same group).

Table 3 - Citation Rates for Various Source and Citation Groups

Source Group	Cited Group	Number of Citations a	Number of Potential Citations b	Citation Rate $\frac{100a}{b}$
Source Articles	PSS	10	828	1.2
	GSA	11	646	1.7
	CDS	2	1266	0.2
Self-Citation	Source Articles	54	1671	3.2
	PSS	228	1259	18.1
	GSA	12	207	5.8
	CDS	50	576	8.7

The self-citation rate for the original set of source articles (3.2%) is increased to 8.1% if the group is reduced to the 29 which were written in or after 1960 and the self-citation rate for Group PSS (18.1%) reduces to 12.7% if one eliminates books and includes only articles published in journals. Other values in Table 3 change very little when such restrictions are introduced to take account of possible variations in citation patterns with differences in date range or type of publication.

The main point which emerges from the data in Table 3 is the very low rate of citation by the original source articles of information published in journals which are not specifically devoted to science education.

DISCUSSION AND CONCLUSION

The foregoing information about citation behaviour shows that, for this particular group of science educators,

(a) 81% of all citations are to works which support the point of view of the source article;
(b) 13% of the citations are to works in which views, different to those in the source article, are presented and in only 4% is the disagreement dealt with in more than a perfunctory manner;
(c) For three groups of papers not published in science education journals but centrally relevant to discussions about the nature of the scientific attitude the citation rate in the source articles was less than 2% of the domains of potential citation.

Great stress is placed by the group of science educators under discussion on the importance of the scientific attitude in science (and in science education) and, in particular, on the crucial role played by empirical evidence in this conception of the scientific attitude. Thus it is somewhat anomalous that almost no reference is made to the wealth of information about the personalities of scientists and the norms of scientific conduct which has emerged over the past 20 years. Most (but not all) of this literature presents a point of view about the scientific attitude which is contrary to that promoted in the science education literature (Gauld, 1982).

However, if one abandons the notion that the scholarly enterprise is directed by the empiricist version of the scientific attitude in which free consideration is given to all relevant evidence (both positive and negative) and replaces it with the view that scholars are generally biased in favour of theories to which they are currently committed one can begin to make sense of the above data. Similar patterns of citation behaviour have been found for scientists in anthropology, human genetics, social studies of science (Spiegel-Rosing, 1977) and high energy physics (Moravcsik & Murugesan, 1975; Chubin & Moitra, 1975).

Science education is surely better served by a conception of the scientific attitude which acknowledges the personal and social constraints within which a scholar actually works than one which, more and more, is being shown to have little to do with scientific practice.

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ATTITUDE TO CONSERVATION OF THE ENVIRONMENT AND AWARENESS OF ENVIRONMENTAL ISSUES

M.N. Maddock and K. McDonald

This paper reports follow-up research carried out in 1981 to studies in 1977 and 1978 evaluating achievement in Hunter Valley high schools of the N.S.W. Secondary Schools Science Syllabus aim:

> To develop in the pupil a belief in the value of conservation of the natural environment. (Secondary Schools Board, 1973A).

The research sheds further light on the information input attitude formation relationships and makes a further contribution to the 'state of the art' in attitude measurement techniques (Doran, 1977) using the Attitude to Conservation of the Natural Environment Scale (ACNE).

Johnstone and Reid (1981) have pointed out the increasing importance placed on attitude growth in schools and the need to relate attitude growth to cognition. Although the literature concedes that information input is an important part of the attitude formation process, there is still uncertainty in the field of attitude research in general and attitudes to conservation in particular as to just what part information plays, the relationship between factual knowledge concerning environmental issues and attitude being regarded as fundamental (Young, 1980).

There would appear to be a widespread assumption that giving information about an issue affecting the community (e.g., logging in rainforests) should result in a more enlightened attitude and hopefully result in an improvement in environmentally responsible behaviour. Young (1980), however, reported that the relationship between knowledge and attitude is not necessarily one of a straightforward positive correlation. He observed that some studies appear to support the proposition whilst other do not. Tichenor, Donohue, Olien and Bowers (1971) found that it was the most highly informed persons who frequently opposed conservational restrictions. Young's (1980) research on the issue of wilderness established a general positive relationship between information and approval. He stated (p. 30) that the amount that people know about wilderness has a greater influence on their opinions than other characteristics such as age, education, income, or residence. Specific public education programs have been conducted on the assumption that a better informed public will acquire more positive attitudes.

Some research findings have questioned the efficacy of such public education procedures. For example, in studies of changing public attitudes towards mass transit facilities, and the use of water reclaimed from domestic sewage for various purposes, Bruvold (1973) found relatively weak relations between any one belief and attitude, and between attitude and any one behaviour. Indeed, he noted that poorly executed public education programs could have the reverse of the intended effect. This proposition has implications for formal education programs in schools, where poorly executed teaching procedures may result in the students acquiring certain negative attitudes.

The strength of attitudes is generally assumed to be positively correlated with corresponding behaviours, with one of the assumptions of much curriculum construction being that there are reasonably strong links between knowledge, beliefs, attitudes, values and behaviour. Thus the stated aim in the N.S.W. Secondary Schools Science Syllabus of developing in the pupil "... a belief in the value of conservation of our natural environment" no doubt presumes that the pupils will tend to behave in an environmentally responsible manner at least partly as a result of an effectively taught belief. However, the literature (e.g. Schuman and Johnson, 1976 and Ajzen and Fishbein, 1977) does not give grounds for optimism. Lucas (1980) has suggested that the findings of literature in social psychology have had little success in permeating the literature in science and environmental education with a consequence that curriculum designers may be 'flying blind' in presupposing links between classroom achievement in science and attitude to conservation.

A number of studies have raised questions about the implicit assumptions in some school syllabuses. Eyres (1978) found that a sample of Australian Year 10 students performed badly on a test of general knowledge about the environment, yet possessed favourable attitudes towards the environmental issues raised. Richmond and Morgan (1977) and Richmond (1978) made similar findings for students in England. Some studies have revealed that environmental attitudes of school pupils may be positive, except where the object of concern impinges on their own lives (Lucas, 1980). This phenomenon would appear to be widespread. For example, in a study by West and Tapp (1980), considerable differences were found between expressed attitude and actual behaviour with regard to energy conservation practice at a personal level - particularly practices that affect the private motor car. It is in the context of this questioning of assumptions underlying school curricula that the study reported here has been carried out.

THE 1977 AND 1978 STUDIES

In 1977, one of the writers (Maddock), with the aid of Diploma in Education students at the University of Newcastle developed and trialled a pilot version of a scale aimed at measuring attitude to the conservation of the natural environment (ACNE). In 1978 a revised version of the scale was developed and given further trials in the region. Details of the results of these studies have been reported in Maddock (1978, 1979).

Items were constructed in which situations concerning conservational problems were posed, and three alternative choices of specific behaviour in those situations provided, one representing behaviour considered typical of a person holding a positive attitude (scored 3 points), one representing that of a person hold a negative attitude (scored 1 point) and one representing an intermediate position (scored 2 points). An attempt was made to define a precise attitude to a specific social object (conservation) in specific situations, as argued by Defleur and Westie (1963). Items were selected and refined using item analyses based on classical test theory, (e.g. as in Nunnally, 1967).

The scales could be described as tapping a 'behavioural intention' aspect of attitude, as defined by Fishbein and Ajzen (1975) and Triandis (1975) and the situations in the items bear features which are somewhat akin to the upper levels of specific, real-life, behaviour in Jordan's (1974) 6 categories for attitude-behaviour scales. The original idea for using specifics of behaviour and situation developed by the author in research in Papua New Guinea (Maddock, 1973) was stimulated by the instrumental approach used by the Kluckhohn and Strodtbeck (1961) study of values.

THE 1981 STUDY

In 1981, the ACNE scale was further refined to a 26 item scale and administered to a sample of over 500 students in grades 7-10 from 24 classes in 7 Hunter Valley high schools. A further scale to test awareness of environmental issues was developed and administered to the same sample at the same time. The new AEI scale was a 39 item, multiple choice scale, with right-wrong scoring, in which the items tapped the knowledge of the respondents concerning a wide variety of current environmental issues such as pollution, nuclear power, pesticides, use of resources and wildlife conservation.

The sample used consisted of classes being taught by the 1981 Science Curriculum and Method students in the University of Newcastle's Diploma in Education program and the tests were administered and data prepared for analysis by the students. The classes ranged from 'high ability' to 'low ability' classes from a range of school types, regarded as being representative of the Hunter Valley high school population. Results on separate classroom achievement tests in science were also obtained from the classes tested and correlations carried out between scores from ACNE, AEI, the achievement tests and IQ as obtained from the pupil record cards.

RESULTS OF THE 1981 STUDY

Reliability and Score Range

Although the number of items in ACNE had been increased from 22 in 1978 to 26 in 1981 and the wording revised for those items identified in the earlier studies as needing improvment, the coefficient alpha reliability of 0.64 was about the same as that obtained in the 1978 trial. This was lower than expected but still satisfied Nunnally's (1967) criterion for suitability for research. The AEI scale proved to be highly discriminatory, with a coefficient alpha of 0.89.

The score distribution for ACNE (in a total possible range 78 - 26) was from 75 to 40. The distribution was symmetrical about the mean of 59.4, which is more to the positive end of the continuum than to the negative end, indicating a positive trend in the attitudes of a significant proportion of the sample.

The overall mean of 14.2 for the Awareness scale in a 0 - 39 score range indicates that the level of awareness in the sample of current issues in conservation was very limited. In the total sample of over 500 subjects only 1 individual scored the maximum of 39, and only 18 subjects scored above 30 points (about 4 percent of the sample). The distribution pattern was strongly skewed towards the lower end of the scale, with 27 percent of the sample scoring less than 10 points.

Across-grades Analysis for ACNE

A one-way analysis of variance was carried across grades 7 - 10. The F value of 2.55 indicated no significant difference between the means and no upward trend across the grades (see Table 1). The 1981 results can be compared with the results of the earlier studies by examining the plots of means (top, and bottom left) in Figure 1. It should be noted that in the 1977 and 1978 studies the scale was a 22 item (score range 22 - 66) scale while in 1981 the number of items was 26 (score range 26 - 78).

TABLE 1. Across grades one-way analysis of variance

ACNE 1981

No. subjects	515		Score range 26 - 78		
Grade	7	8	9	10	O'all
Mean	59.9	58.8	58.0	59.8	59.4

ANOVA

	DF	SUM SQ	MEAN SQ	F	P
Grade effect	3	214.2	71.4	2.55	0.06
Error	511	14334.9	28.1		

Correlational Analyses

When classroom achievement tests in science were correlated with results on ACNE, the majority of correlations found were again of a very low zero-order, as in the previous two studies. In one group of 57 grade 10 students in one school which took a common science test, the correlation was -0.23. In only two of the classes where achievement tests were run did the correlations reach 0.3.

The correlation between ACNE and AEI was 0.17 and even when corrected for attenuation was still a very low 0.22, indicating that in this sample there is very little relationship between students' level of awareness of issues and their attitude towards conservation of the natural environment. The correlation between the attitude scale and IQ was only 0.15, indicating very low relationship between attitude and IQ, whereas between the Awareness scale and IQ it was a significant 0.60, representing about 36 percent of common variance between the scores on AEI and IQ. The correlation between class teachers' estimates of ACNE scores (made before the test was administered) the scores on the attitude scale, was only 0.02, showing that the teachers had virtually no idea of the attitudes held by the students. The main correlation results are summarized in Table 2.

TABLE 2. Results of correlational analyses 1981

	ACNE	AEI	IQ	CT ESTIMATE ACNE
ACNE	1.00			
AEI	0.17	1.00		
IQ	0.15	0.60	1.00	
CT ESTIMATE ACNE	0.02	-0.08	-0.17	1.00

Across-Grades Analysis AEI

In marked contrast to the results obtained with the attitude scale, the grade level effect found in the ANOVA conducted with Awareness of Environmental Issues Scale results were significant, with a distinct upward trend with increasing grade level (see Table 3 and the bottom right plot in Figure 1).

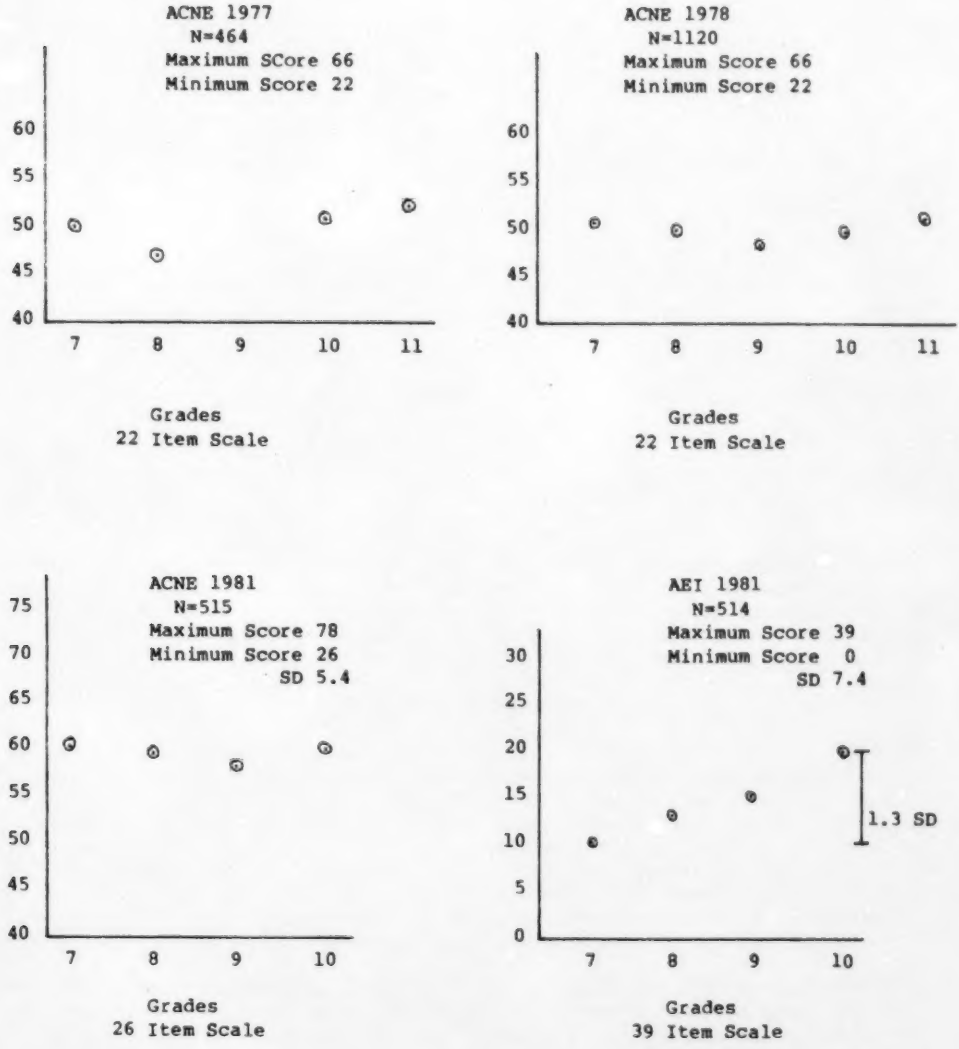

FIGURE 1. Attitude to conservation of the environment (ACNE 1977-78-81 and awareness of environmental issues (AEI) 1981

The F value was 90.7 (df 3/510, $p < 0.001$), with the difference between the grade 10 mean of 19.0 and the grade 7 mean of 9.5 scale points representing 1.3 standard deviations, a difference of major proportion. The epsilon, calculated from the F value (Cohen, 1965) was 0.59, indicating that grade level differences accounted for about 34 percent of the variance.

TABLE 3. Across grades one-way analysis of variance

AEI 1981

No. subjects	514	Score range 0 - 39			
Grade	7	8	9	10	O'all
Mean	9.5	12.9	15.2	19.0	14.2

ANOVA

	DF	SUM SQ	MEAN SQ	F VALUE	P
Grade effect	3	7847.1	2615.7	90.7	0.000
Error	510	14707.8	28.8		

Scheffe post-hoc tests of significance for differences between specific grades (Kerlinger and Pedhazur, 1973, p. 128-131) showed that significant differences occurred between grades 7 and 8 and between grades 9 and 10 at the 0.001 level. For grades 7 and 10 the differences in means of 9.5 was considerably in excess of the Scheffe S of 2.4.

DISCUSSION OF RESULTS

When Doran (1977) reviewed the 'state of the art' in the use of affective domain instrumentation and reported studies which used a number of techniques such as the semantic differential, Likert and Q Sort, he claimed that it was still 'embryonic' and that attempts should be made to further measurement devices, the task being 'difficult but essential to the stability and maturity of the discipline' (Doran, 1977, p. 61). The studies in the development and trailling of ACNE over the period 1977-81 have tested a new instrument, using a different style of construction, which has produced results that shed further light on information-attitude relationships.

Although the coefficient alpha reliability level of ACNE was not increased over the level obtained in the 1978 study, it was still sufficiently high for the scale to be regarded as a useful research instrument and the potential still exists for further improvement.

The results of the cross-grade analysis supported the findings of 1978-79 that increasing grade-level of formal schooling is not a factor affecting attitude scores. In all three studies there was no evidence of any consistent increasing trend in the attitude scores over the years of high school education. Although there are many uncontrolled variables at work affecting the attitude under study, and an increasing trend, if found, could not have been attributed solely to any part of the implicit school curriculum, including studies in science, the lack of any trend strongly suggests that what is done in the schools of the sample is not an effective modifier of attitude to conservation of the environment. However, the overall mean for the sample was slightly towards the positive pole of the continuum, suggesting, to use the Eyres (1978) expression, that a significant number 'have their hearts in the right place, so they say'.

In the case of the Awareness of Environmental Issues scale, the disturbingly low overall mean supports findings by Eyres (1978) that Australian students 'don't know much', even though the data shows that the longer the students stay at school, the more aware they become. The authors doubt whether the courses experienced at school have contributed much to this development, and consider outside influences such as the media are more likely to have been a major factor. The Eyres (1978) study found that only 42 percent of the sample reported special courses and 35 percent general school sources as the source of their knowledge, over 60 percent believing that their environmental knowledge came from non-school sources. Eyres also found 'private reading and media' students were significantly more knowledeable.

The correlational analyses confirm the findings of the 1977 and 1978 studies (Maddock, 1978, 1979) that there is very little relationship between the conservation and classroom achievement in science, as indicated by tests based on the science courses taught in the Hunter Valley high schools, and that the attitude scores appear to be unrelated to IQ scores reported on pupil record cards. They also indicate that classroom teachers are unable to predict çonservational attitude in their pupils. There is also low relationship between the level of awareness to environmental issues and attitude to conservation, although a significant relationship was found between awareness and IQ scores. Students with higher IQ were shown to be more likely to be aware of issues than those with lower IQ.

THE NEED FOR FUTHER RESEARCH.

The situation today is still much as it was when it was stated that there is little agreement about what an attitude is, how it is formed or changed, and what role it plays in influencing or determining behaviour (Fishbein and Ajzen, 1975, preface). However, Fishbein and Ajzen (1975, p. 387) maintained that the centrality of attitude remained unchallenged, its importance had increased, and there was consensus about an informational base being a key factor. The question of what information and how it can be presented has still not been solved in a manner which is of very much use to curriculum developers or practising teachers. Despite whether schools emphasise them or not, pupils will develop attitudes and 'such attitudes may develop without a satisfactory cognitive base' (Johnstone and Reid, 1981). The study reported here does not give any confidence that the information provided either by the implicit or the hidden curriculum forms any satisfactory cognitive base.

Lucas (1980) in his comprehensive review on science and environmental education seriously questioned the value of the attitude concept in the environmental education concept. He advocated the examination of science and environmental education programs for their effects on behaviour, and not on attitude change alone and research which attempts to establish causal relationships and not merely correlation, between knowledge, behavioural intentions and behaviour (Lucas, 1980, p. 20).

The authors agree that desirable overt behaviour is the ultimate goal to be achieved and that causal relationships should be sought, nevertheless, attitudinal goals are still explicitly defined in curricula and their outcomes need to be evaluated. In the N.S.W. situation, an appropriate attitude is clearly a required outcome and the incorporation of attitudes into assessment is still policy (Secondary Schools Board, 1973B). Information concerning the relationship between attitudes and other variables can be fed back in the curriculum development, policy revision process and classroom teaching process. If there is no success in achieving specified attitudinal goals then either the goals or the curriculum approach need to be changed.

Attention has frequently been focussed on short-term, one-shot types of studies, and very few findings have been made of any real assistance to the curriculum developer or classroom teacher. In fact, the insistence of psychologists on very tightly controlled experimental situations has tended to result in a host of what the authors consider to be quite trivial findings, focussed on a very small part of social behaviour as discussed by Brislin (1980, p. 2). Guthrie (1975) pointed out that only some social variables can be manipulated for only a few minutes or an hour at the best, and 'we know that the duration and intensity of these treatments are slight compared with the social pressures of everyday life' (p. 103).

The three studies have resulted in the Attitude to Conservation of the Environment Scale and the Awareness of Environmental Issues Scale being developed to a stage where they could usefully be used in future intervention studies using specifically designed 'environmental education programmes', where different kinds of information input and different methodologies could be investigated and for research in the broader adult community.

The use of highly specific situations and related behaviours in the ACNE scale attempts to bring the concept of attitude closer to the behaviour domain. By searching for relationships between attitude and other variables, there is some hope of finding information of value to the framers of curriculum and policy makers and for providing advice to teachers. The negligible relationship between the attitude and awareness of environmental issues and knowledge gained in classroom science lessons in high school students shown by this result, when added to the findings by Eyres (1978), suggests that the aims and objectives, content and classroom approaches are certainly in need of review, particularly in N.S.W. and the Hunter Valley.

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PUPILS' PRESCRIPTIONS FOR GOOD SCIENCE TEACHERS

L. Endean

INTRODUCTION

Improvement Research

Hogan (1980), reviewing types and directions of educational research in Britain over recent years, has drawn attention to the widely-quoted and accepted definition enunciated by Nisbet and Entwhistle (1973) that 'educational research consists in careful, systematic attempts to understand the educational process, and, through understanding, to improve its efficiency'. Whilst these writers make it clear that they recognise the existence of pure and applied aspects of educational research, they stress that 'a definition which includes the notion of "improvement" is increasingly being applied in deciding priorities in educational research'. The giving and witholding of funding determines to a large extent which proposals will be put into effect.

Funding agencies may be attracted by concepts of 'improvement', 'efficiency', and 'effectiveness', but 'improvement' research seems likely to alienate teachers. They often reject the findings of such studies not only because of what they see as threatening and demeaning implications, but also because they feel that the models of teaching employed by the researchers are simplistic and inadequate. The models are seen to be unrelated to the real world of the school and classroom, being based on theoretical constructs in the researchers' minds, rather than on experience and individual cases.

The 'Black-Box' Approach to the Classroom

Most research approaches appear to have a universal quality, as results of similar methodologies and theoretical stances appear in English, German, Russian and French research literature. Almost without exception, research in teaching has largely ignored the richness and complexity of the classroom. It has been seen as a 'black-box' with a mechanism that had little relevance or importance to the research plan. It is not surprising therefore that the past discoveries, answers and conclusions of researchers appear to have been more for each others' consumption via the medium of the research journals, and to have had no significant effect upon the practice of teaching. In fact, some researchers (for example, Hamilton and Delamont (1974), Lamborn (1980) and Dunkerton (1981) have been warning other researchers that the very approaches and philosophies underlying their studies, as well as the methods employed to communicate them, practically guarantee this state of affairs.

Potentially fruitful strategies to overcome the impasse have recently been suggested by Elton and Laurillard (1979) and Lamborn (1980). Lamborn integrated the reasoned contention advanced by Elton and Laurillard that 'much research was essentially irrelevant to practice, i.e., it was intrinsically incapable of linking with the latter, and what was required was a new formulation of both, the problems that research could tackle and the methodology which it should employ', with Harre's analysis of realist

science, and developed what he terms a 'tool-making tool'. An approach is outlined by which a teacher uses his own knowledge and model of teaching to develop a means of examining, elaborating upon, enriching, extending and/or refining it in a feedback research sequence in which the teacher and not the researcher alone is central to the experimental treatment. Such an approach was envisaged as being likely to go some way towards removing the alienating aspects of research on teaching in that the teacher would cease to be conceptualised as a work unit, or uniform cog in a machine, but would be involved with the researcher at the level of his own curiosity.

A PARTICIPANT APPROACH TO CLASSROOM RESEARCH

The Science Classroom Management Project (Butler, Beasley, Buckley and Endean, 1980; Endean, Beasley, Buckley and Butler, 1980) was commenced with the objective of clarifying with the classroom participants the events and interactions occurring in junior science classrooms in south-east Queensland secondary schools. Not only have teachers and pupils seen and commented upon their own videotaped science classes, but also results have been fed back at regular intervals to teachers in forms which they could discuss, explain, and criticise. The teachers in the study themselves suggested the timing of the second phase of the study. This was as a result of a problem enunciated by the researchers that, with the first phase classes videotaped in the middle of the year, there appeared to be many covert rules of interaction between class and teacher which were not readily accessible to the trained observer. Teachers recommended that the early weeks of the school year would provide insight into the negotiations from which spring the classroom dynamics. They stressed certain variables which they said were of critical importance in the time taken to establish the modus operandi and its quality. In particular, their insistence on the importance of teacher 'presence' led to a whole new phase of the study and analysis of non-verbal behaviour in classrooms.

Pupils as 'consumers' of the science classroom offerings have also been consulted, and following the methodology of the trained observers, have rated teachers from other classrooms on non-verbal characteristics, the detail of which is reported in another paper (Wilson and Butler, 1982) appearing in this publication. When asked to describe the characteristics of the ideal junior science teacher in the same non-verbal terms, the pupils were readily able to do so, and their 'ideal' bore a close relationship to the upper group of observed teachers. Both the teachers rated as being in the top group and the 'ideal' teachers displayed behaviours which made sense in terms of the teachers' own concept of 'presence'.

THE IDEAL JUNIOR SCIENCE TEACHER THROUGH PUPILS' EYES

The picture which emerged about the ideal junior science teacher was of a self-confident and relaxed individual, who assumed backward-leaning and asymmetrical postures, made asymmetrical gestures, used language fluently and syntactically with pleasant and effective voice production. The teacher exerted a good deal of dominance over the class, but this was of a benign rather than threatening kind — a calmly confident teacher, firmly in the driving seat, running an organised and busy, but not too tight, ship.

In a rather different context, another study (Endean and George, 1982) was carried out to elicit a written description of the ideal science teacher and the ideal science classroom from the point of view of a group of thirteen year olds who had been selected by their own schools in Northamptonshire, England, to attend a special summer school for 'gifted young scientists'. The youngsters in this group were very diverse in their cognitive styles, from

highly convergent to highly divergent. They had been selected by their schools as showing great promise in biology, chemistry, or physics. Others showed excellence across the board in the sciences. The pupils also came from varied socioeconomic backgrounds, and the schools from which they were drawn spanned the spectrum of school types in the county. Yet when their responses were analysed it became clear that these bright, diverse, and highly motivated pupils displayed a remarkable consensus about many of the characteristics of ideal science teachers and ideal science classrooms.

Their ideal science teacher is described as being able to manage the class, keep it working at a good rate, and keep everyone on task without resorting to unpleasant or overbearing tactics. A master of the subject-matter who exudes confidence, the ideal teacher is able to present it in an interesting and motivating way. While 'strict' in the sense of having clearly negotiated classroom rules, the teacher possesses a good sense of humour and is able to keep order in class without using repressive measures such as forcing the pupils to work in complete silence. At the same time this teacher is able to deal swiftly and effectively with disruptive pupils.

The respondents considered the teacher's relationship with the pupils to be important. He/she ought to be concerned about their learning, prepared to exercise patience and take time with individuals in order to explain again the concepts which at first were not understood. Equally importantly, he/she ought to be prepared to explain an individual's mistakes and clarify misconceptions on a one to one basis.

The ideal teacher is able to communicate well with pupils using every day language rather than scientific jargon and everyday examples drawn from the home and industry. Analogies are used skilfully to make new concepts easy to master.

Some Differing Prescriptions

A sub-group (all girls) wanted a teacher who would be prepared to let them first work out their own explanations for observed phenomena, their own interpretations of experimental results, devise and set up their own experiments and then to permit them to argue for them. That is, they wished to establish or abandon their ideas as a result of debate after they had tried an idea or experiment out. They seemed preoccupied with assessing different possible methodologies, and some requested a minimum of teacher interference before an experiment was done. The teacher's role was seen as making equipment, reagents etc. available and leaving the pupils to get on with it on their own. Afterwards the teacher was required to assess and criticise work completed.

Such a teacher-type was in marked contrast to what most of the boys wanted. They wished the teacher to give a detailed and precise step by step account of how to set up and carry out experimental work and get 'the result' quickly. In fact, there was a distinct sexual dichotomy in some of the expectations and aspirations of these able youngsters. Interestingly, these matched up almost exactly with the findings of the 1980 DES-funded Girls and Science study, which was set up to investigate factors that appeared to affect whether girls in Britain's secondary schools stayed in or dropped out of courses in the physical sciences after completion of the early grades.

The physical arrangement and organisation of classrooms was recognised as being of importance. The ideal science classroom with few exceptions was characterised as being well-equipped with plenty ('limitless', many said)

materials, and a small number of pupils. Most respondents asked for a class of from eighteen to twenty pupils, all of whom were keen to learn. Some (girls) asked for even smaller groups of no more than ten pupils, with more than one teacher. The ideal classroom was to have been well designed so that each pupil would have an individual work space where experiments and writing up could be done. There was unanimity that this kind of well designed and organised room would result in a great deal more of their work being experimental. The pupils felt that an experimental approach would aid them in grasping new concepts quickly. They wanted the atmosphere to be quiet and orderly, but informal and friendly.

CONCLUSIONS AND PROSPECTS

On one hand we have senior pupils viewing unknown teachers in junior science classrooms in south-east Queensland secondary schools and rating them on non-verbal behaviours. On the other we have able junior science pupils from Northamptonshire writing about their ideal science teacher and classroom. It is not difficult to discern similarities in their descriptions, nor is it difficult to relate what is said about vital behaviours for effective classroom management by both groups of pupils and by teachers themselves.

It is proposed that the combination and integration of teachers' and pupils' models is likely to give a more useful insight on effective classrooms than many other models which have been conceptualised and researched without much reference to the participants. Teachers tend to think clinically because that is the way they operate, as it were by coalescing and reflecting upon cas histories. They develop intense cybernetic qualities in their work, and it is these which give them a base from which to operate in the real world of the classroom. This set of insights and skills may well form the basis for the employment of what Lamborn refers to as the tool-making tool. As such the teacher may use his own knowledge and model of teaching to develop a means of examining, elaborating upon, experimenting with, enriching, extending or refining it in a feedback research sequence in which he, the teacher, and not the researcher alone, is central to the experimental treatment. A meaningful way of assisting this process is by taking pupil experience (not necessarily from that teacher's own class) into account. It certainly would seem that teacher awareness of differing expectations would facilitate conscious and deliberate interaction rather than that which is based merely on intuition. The researcher in this process is one of the team who must be prepared to respond to feedback in what he does and in relation to the conceptualisations of the classroom participants. The insights gained from this type of research in the Science Classroom Management Study seem to be useful, not only from the theoretical viewpoint (the researchers' preoccupation) but also from the perspective of teachers. This alternative research model facilitates communication and sharing of information much more than can an academic paper appearing in a research journal. Even if such articles are read, it is common enough for teachers to fail to see in them any real relevance to their own situation.

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MATRICULATION STUDENTS' PERCEPTIONS OF THE SIMILARITY OF SCIENCE COURSES OFFERED BY TERTIARY INSTITUTIONS IN QUEENSLAND

M.P. McFarlane and B. Cameron

INTRODUCTION

Academics in tertiary institutions are becoming more aware of the need to examine the nature of student demands for their courses (Cameron, 1981). This examination is in many instances brought about by pressures to 'rationalise' tertiary education in the face of decreasing funding. Such pressures may result in a questioning of the viability of particular courses in terms of enrolment and also the need for them when courses bearing the same name and offered by other institutions are taken into consideration.
Such pressures tend to cause reviews which attempt to

- justify the continuation of a course in the grounds that it serves a particular function either by its character or by its particular geographical location,
- reformulate, modify or refocus the emphasis and character of the course to better serve, or to be seen as more relevant to the needs of a significant population of students,
- formulate policies and practices for promoting and communicating the benefits and significant characteristics for an existing course for purposes of increasing the levels of student enrolment, or
- discontinue the course, or significant parts of the course, or the similarity of courses being offered elsewhere.

In practice, these reviews tend to reflect the opinions of those who provide such courses. Opinions are often based only upon academic discipline and course content considerations supplemented by some data which reflect enrolment histories, speculative employment requirements, and opinions of current and past students about their courses. Yet crucial information for many of the decisions relating to the four major areas of change as listed previously, is to be found in the perceptions and beliefs which potential students hold about course characteristics.

Information about whether courses are perceived by potential students as being similar or different, and in what ways, may be useful for those who wish to initiate actions which might alter student enrolments, either through modifications of existing courses, or by altering beliefs about the merits of particular courses. This study arose out of such considerations; it was primarily concerned with exploring the perceptions matriculation students have of the tertiary science courses currently available in Queensland.

OUTLINE OF THE STUDY

This study had two broad objectives. Firstly, it was concerned with exploring the perceived similarities amongst science courses offered by six tertiary institutions in the State of Queensland: Capricornia Institute of Advanced Education (CIAE), Darling Downs Institute of Advanced Education (DDIAE), Queensland Institute of Technology (QIT), Griffith University (GU), James Cook University (JC) and University of Queensland (UQ).

Secondly, it attempted to identify attributes which might explain patterns of similarities amongst science courses. In particular, the study was concerned with representing this information in a way which might be helpful to decision makers involved in making course modifications. In designing the study it was recognised that students' perceptions might be based upon vague notions rather than accurate information - sentiments echoed in Litten's (1979) study of institutional image. Furthermore, it was recognised that these notions might well be unrelated to the commonly held views of academic staff.

METHODOLOGY

The study used a three-part survey mailed to students.

A pilot study had been conducted amongst 296 students who had indicated a preference for studying science at the Darling Downs Institute of Advanced Education; 120 responses were returned. Using information gleaned from this study, Sections B and C of the instrument were revised to include features commonly mentioned as being either 'most attractive' or 'least attractive'.

The three parts of the survey (Comparisons of Tertiary Science Courses - 02) could be briefly described as follows:

Section A — Respondents were asked to rate the similarity of pairs of science courses at the six institutions using whatever criteria they felt were important. In addition students were asked to list the most attractive and least attractive features of each of the science courses.

Section B — Respondents were asked to rank each of the science courses upon a set of attributes derived from discussions with a group of science staff on the attributes they felt were important to students in differentiating amongst science courses.

Section C — Respondents were asked to rate the importance of each of the attributes to their choice of a science course.
Sample items for rating in this section were:

1 'practical'-'theoretical' nature of courses
2 level of entry required
9 reputation of the course
13 recommendations from teachers.

The instrument was then distributed throughout the State secondary schools to matriculation students who were contemplating studying tertiary science. Guidance Officers had agreed to assist with the data collection. The insights gained from the 104 usable returns are necessarily tentative. Distribution difficulties experienced by the Guidance Officers led to the obtained sample being much smaller than anticipated.

ANALYSIS AND RESULTS

The approach was based upon multidimensional scaling techniques used by Green and Carmone 1970 and Green 1975. Multidimensional scaling analyses (MDS) of Sections A and B were performed using ALSCAL4F (Young and Lewyckyji, 1979) as implemented on a HP3000 computer.

The similarity judgements and the ranking data were assumed to be at the ordinary level of measurement. The INDSCAL option was used for Section A and a multidimensional unfolding approach was used on the grouped data of Section B. The Rasch simple logistical model as extended by Andrich (1975) was used to scale the attributes in terms of their importance in the choice of a science course (Section C).

Figure 1 depicts the group stimulus space of student perceptions of the similarity of the six tertiary science courses using a two dimensional representation (SSTRESS (average) = 0.2; RSQ (average) = .73).

It is interesting to speculate on interpretations of the dimensions. Dimension I seems to be distinguishing between the sizes of science courses in terms of the numbers of students enrolled and diversity of courses, (i.e., UQ and QIT science compared with the other smaller courses). Dimension II appears to differentiate between university science courses and those offered by the colleges of advanced education. However, apart from speculation, there is little evidence from this analysis alone upon which to base meaningful interpretations of the dimensions. Nevertheless, the science courses offered by the two smallest colleges (CIAE and DDIAE) are perceived to be most similar to each other. The courses offered by the two smallest universities (JC and GU) are also perceived as similar. The science courses offered by the University of Queensland are perceived as being most similar to those offered by the largest of the colleges, Queensland Institute of Technology.

In analysing students' ranking of science courses upon the attributes listed in Section B of the survey, the data was aggregated by calculating the median ranking of each science course on each attribute. (This was done because of space limitations on the HP3000). A multidimensional unfolding analysis (MDU) was performed in which both the objects (science courses) and attributes are represented in joint multidimensional space (Young and Lewjckyji, 1979, p.5). The spatial pattern of the courses appeared to be similar to the group stimulus space of Section A.

In ordere to relate the two sets of data, an MDU was performed in which the stimulus co-ordinates (science courses) were fixed according to their relative positioning derived from the analysis of Section A. Values for SSTRESS (av) = 0.12 and RSQ (av) = 0.99, in a two dimensional space were obtained. A more pragmatic test of whether or not the derived configuration matched the aggregated rankings of the science courses on each attribute indicated that the data from both Section A and Section B of the survey could be represented on the one grouped two dimensional space. This configuration is shown in Figure 2.

It is important to note, that the evidence does not suggest that all of the important criteria students used in judging the similarity of science courses were those and only those attributes used for ranking courses. Rather the indication is that whatever else may have been used by students in performing their tasks in Section A, it is likely that such attributes, if known, could also be included in the multidimensional space. Thus, there is some indication of the stability of the perceived relative similarities of these science courses. These similarities may be examined in terms of their proximities to the various attributes employed in the study and others which were not, and are still unknown.

In interpreting Figure 2, it is important to consider the relative distance of each attribute from each of the courses, since only ordinal level measurement was assumed. Thus UQ science is perceived as requiring the highest level of

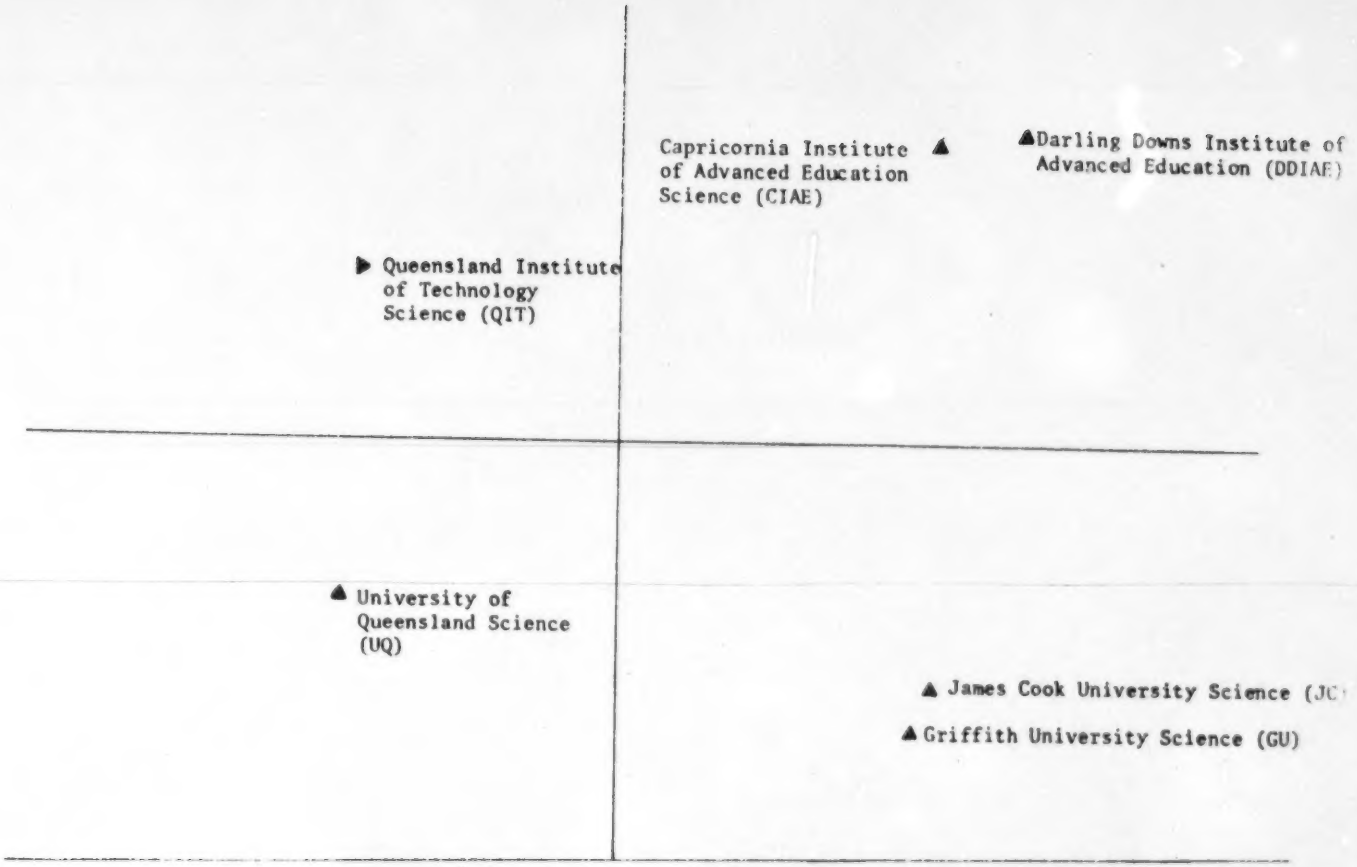
Capricornia Institute of Advanced Education Science (CIAE)
Darling Downs Institute of Advanced Education (DDIAE)
Queensland Institute of Technology Science (QIT)
University of Queensland Science (UQ)
James Cook University Science (JC
Griffith University Science (GU)

FIGURE 1. Multidimensional scaling plottings of the perceived similarity of six science courses offered by tertiary institutions in Queensland.
(2 dimensions; SSTRESS = 0.02; RSQ = 0.75)

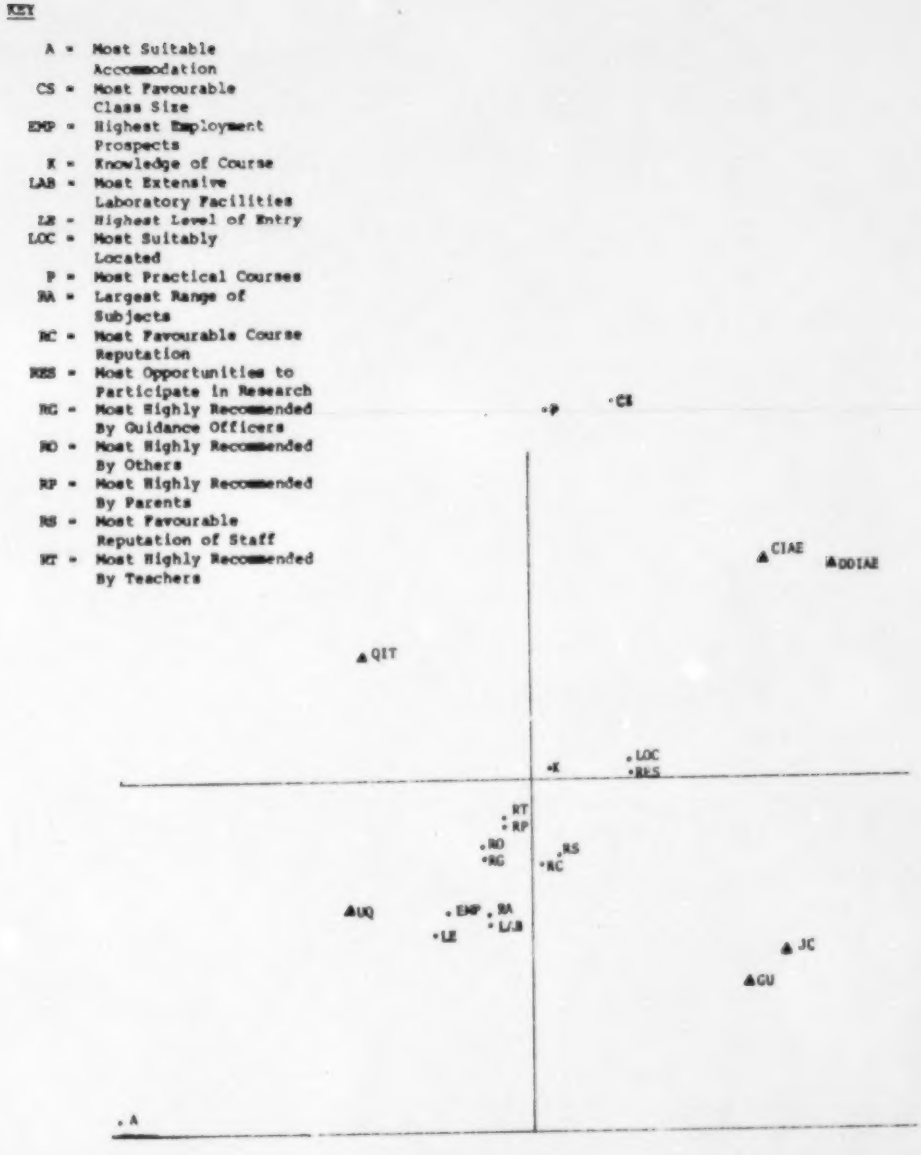

Figure 2. Two dimensional configuration of science courses in relation to 16 attributes. It was derived from a multidimensional unfolding analysis in which the co-ordinates of the science courses were fixed. (SSTRESS = 0.12; RSQ = 0.99)

entry, and DDIAE science the lowest. Simiarly, UQ science is perceived of as having the most favourable reputation and DDIAE science the least favourable reputation.

The Rasch simple logistical model as extended by Andrich (1975) to attitudinal data was applied to the data of Section C to scale the attributes in order of their perceived importance in the choice of a science course, in a way which is independent of individual's 'attitudes' to rating process. The effect of such scaling is to produce a probabilistic Guttman scale of item affectivities, i.e., the tendency of the items to elicit responses in similar directions. The data fitted the model, and the scaled affectivities are shown in Figure 3.

The attribute 'employment prospects on completion' is regarded as most likely to elicit ratings towards the 'very important' end of the rating scale as compared with the other attributes.

It should be noted that while attributes such as 'recommendations of parents' have the least relative tendency to elicit responses towards the 'very important' end of the scale, they cannot be dismissed as unimportant per se. The scale is a relative scale, and it may well be, that of all the possible issues that might have some importance in the choice of a science course, parental recommendations is placed in the top twenty. Furthermore, when one ponders the question as to what might be the substance of personal recommendations, it may be quite likely that parents, teachers and guidance officers communicate their recommendations in terms of some of the other attributes and it is the substance of these recommendations which students regard as being more important to the choice of a science course, rather than the fact that the recommendations were made by particular people as such.

DISCUSSION

The extent to which the multidimensional configurations offer unexpected insights depends to a large extent on the preconceptions and point of view of the interpreter. Thus the perceived similarity of the DDIAE and CIAE courses has surprised some staff who regarded them as having quite different emphases, while most observers would not be surprised at the greater perceived similarity of DDIAE and CIAE science to QIT science than to science courses offered by universities.

Official publications cite the same entry level requirements for all science courses with the exception of the University of Queensland which requires a higher level of entry. Further, published statistics of the entry scores of students who have enrolled in science courses reveal similar patterns of tertiary entrance scores, with the exception of the University of Queensland and the Queensland Institute of Technology which contain a larger proportion of students with higher scores. However, the pattern of student perceptions indicated that students as a group would regard the entry level requirements of university courses as being higher than the two smaller college courses. This may reflect misconceptions on the part of students. What effects these perceptions have upon the attractiveness of science courses is not clear other than that approximately 10 percent of students regarded 'low level of entry' as being an attractive feature of some of the science courses.

It is also interesting to examine the proximity of the attributes used in this study to the science courses offered by the largest institutions in the State (UQ and QIT). Clearly these courses are perceived as having the highest

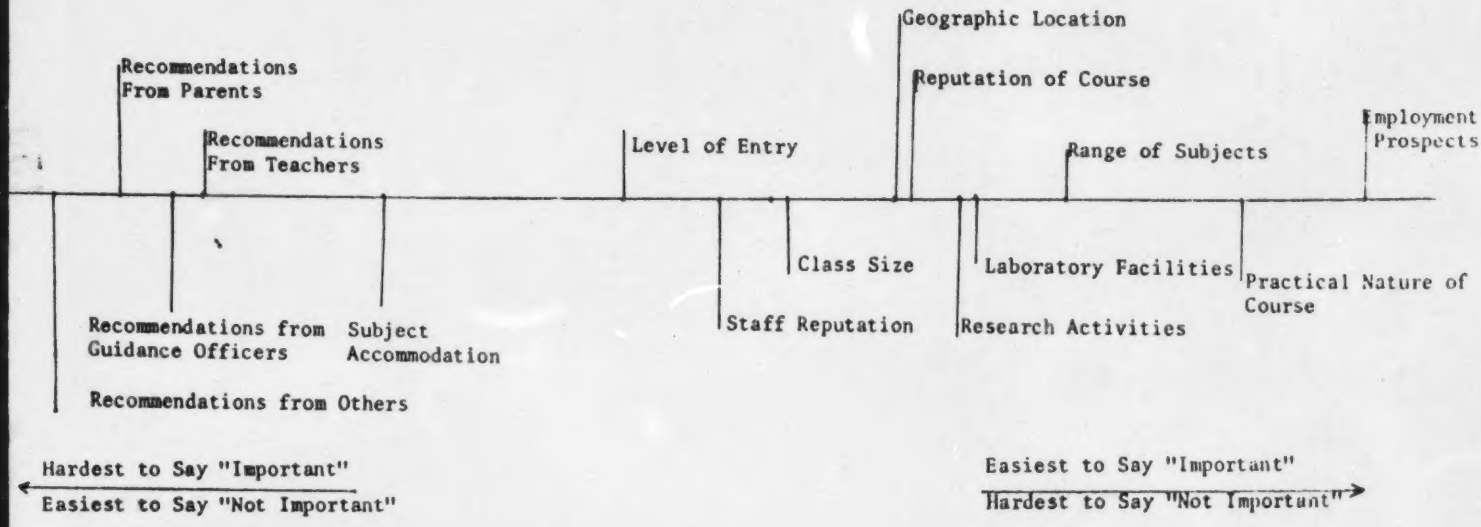

Figure 3. Scaled affectivities of the perceived importance of the attributes in the choice of a science course

prospects of employment on completion, the largest range of subjects, access to the most extensive laboratory facilities, most opportunities to engage in research, staff and courses with the most favourable reputations, the most favourable recommendations of teachers, parents, guidance officers, and others. They seem to have all of the attributes. Bearing in mind that these attributes although prespecified were also gleaned from those features cited by students in the pilot study as being either most attractive or least attractive, it appears as though none of the other science courses are perceived to have characteristics which set them apart from the two largest courses, or which have given them an entity in their own right other than diminished ratings on the full set of attributes. One may have anticipated that there would exist some attributes which were closely associated with each of the particular courses and not so much with others. There appears to be little evidence of this in the study. There are implications, however, for those who wish to develop images for specific science courses.

Furthermore, the relative importance of attributes in the choice of science courses suggests terms one might use in describing courses. Thus there would appear to be some merit in relating characteristics of employment for which the courses may be relevant. This suggestion contrasts with the current relatively sterile publications which often only describe course content and structure in terms only graduates have a chance of comprehending.

The above discussion and reference to the perceived market place represented by the multidimensional figures has attempted to indicate that there are a number of areas about which decision makers concerned with offering science courses might contemplate, prior to action determined from the results of further investigation. This study has focussed upon the perceived broad aspects of science courses and as such has not directed respondents' attention towards considering the many strands of science. Further it has dealt with grouped data and the analyses have not considered subgroups of respondents - metropolitan student perceptions as compared with non-metropolitan students for example. It has been a preliminary study and it is argued that the analyses performed to date have produced useful indications that will serve as a base for additional studies.

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WHAT OR WHERE IS THE 'NATURE' OF SCIENCE TEACHING?

Rod A. Fawns

INTRODUCTION

Critical social theorists have claimed that political and economic forces have a determining influence upon the form and content of the school science curriculum (Young, 1971; Apple, 1979). They also cast the curriculum workers in the role of bearers of symbols of social necessity into schools (Giroux, 1979).

Perhaps if we consider such claims to be extreme or politically committed we would at least admit substance in the claims by historians such as Kliebard (1970) that the production line model and utilitarian criteria have limited the intellectual framework of curriculum workers. If so, it is important that we should pay more attention to expressive elements in the writings and personal utterance of the authors of school science courses, school texts and methods texts. This is simply to argue that there is a literature about science teaching in Australia which has a symbolic as well as an instrumental or technical function.

Where such text writers have had something to say about the context of science education in Australia, attention to the scientific and social imagery they have employed in their writing may help us to understand their commitment and our current professional context. For example in attempts to attribute value to a particular proposal for general science education the symbol of 'nature' has been used to endorse a view of the source of essential knowledge as well as to establish a standard by which science teaching is best judged. The ideas of nature, as revealed in various conceptions of science courses and texts, express the authors' visions of science teachers in the world as priests of nature, representatives of scientific discipline, models of rational man, or stewards of the real world. This essay focuses upon the employment by these science curriculum workers of the concept and image of 'nature' to characterise their purposes. The approach to the analysis of the different fusions of concept and image in the text writings draws tentatively upon the literary critics Barthes (1972), Williams (1980) and Rorty (1980) and needs to be briefly explained. The assumption that the writing in science textbooks and syllabi for example can be seen either as independent of its author, in some way controlled by the language and the history of science texts or else the product of the author's personality, whim or fancy has been rejected. Rather it is claimed that there is a zone of freedom between language and style. Neither strictly historical nor irredeemably personal, there is an aspect of their writing which occupies a middle ground; it was for Barthes 'essentially the morality of form' and for Williams 'form considered as human intention'. This paper sets out to describe the intention in certain important texts that have been used in junior science teaching in Victoria. It represents a complex view of the writings and utterances of textbook authors. The focus is on the writers' consideration of the social use which they have chosen for their text and their commitment to this choice. The textbook authors argue however, that they cannot generally put their texts at the service of a social group or ethical end (as is implied by

Young, 1971; Apple, 1979 and Anyon, 1979); that is to say they do not decide matters of consumption. Textbook authors see the writer's choice - which amounts to a way of conceiving science education - as a matter of conscience as much as of efficacy. The paper is therefore not concerned to attribute bad faith or moral delinquency to the authors of important texts who have erected science teaching into a fundamentally problematic activity. Neither is it an intention to present reality in a prejudged form. There is no writing which can be lastingly revolutionary although the authors that will be quoted here were proposing radical change in their time. The committed writing quoted below illustrates an ambiguous reality. On the one hand, the statements unquestionably arise from a confrontation of the writers with the society of their time; on the other hand, from this social finality, writers are referred back, by a sort of tragic reversal, to the conventions of language and practice in schools; that is, to the instruments of creation of reality.

'Nature' as the Symbol of Permanence and Singularity

The symbol 'nature' is often intended to confer the impression of continuity upon the vision with which it associates. Upon analysis however the vision and the meaning of the symbol are complicated and changing.

Nature as the symbol of stability and continuity was employed for almost two decades postwar in the establishment of General Science in Victoria in place of separate science subjects up to Year 10.

> General Science is a course of scientific study and investigation which has its roots in the common experience of children and does not exclude any of the fundamental special sciences. It seeks to elucidate the general principles observable in nature; without emphasising the traditional division into specialised subjects until such time as this is warranted by the increasing complexity of the field of investigation, by developing unity of the separate parts of that field, and by the intellectual progress of the pupils. (Victorian Schools Examination Board, General Science Syllabus 1949-62)

This was a direct quotation from The Teaching of General Science a report to the English Science Masters Association, 1935.

The nominal continuity expressed in the persistence of this rationale masks the radically different and often unnoticed changes in experience and society over this period of change from colonial legacy to technological age. The sense of fundamental social change is denied.

Another sense of 'nature' as the inherent and essential quality of any particular thing is captured in early descriptions of experimental science as natural philosophy and in elementary science as 'nature study'. 'Natural' seems to have been in this sense tangible or physical, but with the underlying assumption that in the course of the physical enquiries one was elucidating the essential, inherent, intangible and immutible laws of the world. The ideal association of a name for the quality (natural) with the things observed (nature) provided the legitimisation required. As an early Biology method text put it,

> Biology teaching aims at giving the pupils a reverence for nature and for natural laws, thus helping them to lead fuller lives because they have a better understanding of, and truer contact with the world that is governed by these laws. (Phillips and Cox, 1935, p. 3).

The authors seek an essential principle. Nature is seen as a philosopher's stone, a singular name for a social multiplicity of things and living processes. Biology was held by Phillips and Cox to be neutral or natural, as in beyond human manipulation. From the 1930's, the symbol of nature thus offered to science education a dominant kind of stance: idealist, metaphysical or religious. There is a conception or order proclaimed here which reaches through every part of the universe, from the highest to the lowest, a divine order of which the laws of nature are the practical expression.

In description of the aesthetic value of teaching Biology, Phillips and Cox find special meaning in Wordsworth's advice to the unobservant:

> Come forth into the light of things,
> Let Nature be your teacher.

and Tennyson's expression of 'the miracle of the commonplace',

> ... if I could understand
> What you are, root and all, and all in all,
> I should know what God and Man is.
>
> (cited in Phillips and Cox, 1935, p. 28)

Nature's laws were held to be visible to the inner eye. The study of nature then, by revealing the natural laws reveals the essential harmony. In this pastoral view, busy bees will gather sweetness and light thus protecting society from cultural anarchy. Nature can be personified as a paradigm of interdependence and co-operation - an extraordinary interlocking system of mutual advantage. However there is ambiguity here. Nature can be seen as red in tooth and claw, a ruthlessly competitive struggle for existence. The aspiration to know is also ambiguous - to aspire to know the order of nature or to know how to intervene in it - to put it another way, whether to learn one's important place in the order of nature or learn how to surpass it.

The Abstraction of Man From Nature

By the mid 50's the symbol of a singular metaphysical nature, associated with a singular science in school texts such as General Science for Australian Schools (Daniel & Turner, 1943-67), was under attack. The authors of the next dominant text in Victoria, New General Science, James & Rowney (1954-64) felt they could present a clearer and more accurate picture of the purpose of a modern science education by organising it around the language of professional science. Their critical remarks are addressed to commonsense approaches.

> The young, inquisitive mind is disappointed with an advanced nature study course when the magic words, Physics, Chemistry, Astronomy, Biology, Geology, and so on, beckon. In this scientific age, General Science should be scientific and not merely popular science.
>
> ...the division of the book into sections on the different branches of science presents a clear picture to the student.
>
> (James and Rowney, 1954-64).

The clearer, more accurate picture of the general principle observable in nature was presented in 79 chapters at 5 pages per chapter. If this reductionism was a solution to the practical problem of representing diverse and complex nature then the abstraction of nature from experience was the outcome. The activities of man were further distanced from this professional view of nature by the diminished importance attributed to technology in science in texts.

The 'commonsense' frame to which James and Rowney were reacting was understood by science fiction writers such as H.G. Wells in War of the Worlds (1898) and Fred Hoyle in The Black Cloud (1957) who had begun to explore the distinctions between science and fiction, between the conscious and subconscious experience of scientific development upon which science education reclines.

To James and Rowney science teaching could be distinguished from all other teaching by its secure self-sufficiency founded on claims of 'discrete', 'permanent' and thus 'natural' abstract forms of knowledge. Whilst not ahistorical in conception, the treatment given to the history of science in the texts was more expedient that judicious in its chronology of key revelations and its neglect of social conditions.

The separation of man from nature had several implications in this period of rapid economic growth in Australia. The practical distinction between nature and man (science and society) makes it possible to examine economic, educational and scientific processes as natural processes without any prior assumption of purpose or design but simply as mechanical. Science texts could claim to be showing how nature 'worked', what made it 'tick'. The distinction also makes it possible to argue that the conditions of nature can be altered in experiment or improved. Agricultural improvements and technological revolutions are uncritical endorsements of the perspective that sees nature as quite simply for human purposes.

Such a view of science as natural law was consistent with conservative economic theory. The natural economic laws, the natural liberty of the entrepreneur to go ahead without interference, was a projection of the market as the natural regulator, a remnant of social harmony, through which self-interest and common interest might ideally coincide.

Nature is attributed to science and decisively seen as separate from men. Nature is 'out there', and it was natural to reshape it to the dominant need, without having to consider very deeply what this reshaping might do to men. With nature defined as separated from man, the impact of science on society or culture could be described only in marginal terms in school texts. There was 'no room' for issues such as Hiroshima or contraception in any science text. In both his method text Getting Science Across (1968) and in his important science text Pursuit of Science (1964-70) Lugg argued that the essential characteristic of underdevelopment in any community was seen to be 'its failure to become at one with the scientific and technological civilisation which was seen to be the shape and motive free of human progress' (Lugg, 1968, p. 2). He saw human progress being guided by scientists who had certain habits of thinking which should be directly inculcated in each child through good science teaching.

> To gain some idea of the scope of science and its methods, to appreciate and imitate the calm detachment and unemotional judgement of the scientist, to wonder at the neatness and elegance of the scientist's creative function

> in the ordering of knowledge as revealed by generalization and mathematical formulae, to find pleasure in devising a successful controlled experiment, to marvel at the beauty of microscopic protozoa, to contemplate the infinity of space and time, or the remarkable functioning of the human brain, to ponder the two basic assumptions from which science stems, viz., that nature is understandable and nature is orderly; these are some of the enriching experiences possible in a science education.
>
> (Lugg, 1968, p. 2)

Lugg was particularly insistent that the successful inculcation of 'habits of thinking that contribute to the scientific attitude ... ought to be apparent in changed behaviour of the pupils'. (Lugg, 1968, p. 3) There was to him a moral imperative in this alliance of science and nature. Indeed it was written that :

> One of the achievements of a school science course should be the acquisition by pupils of the attitude that wilfully to remain ignorant of an understanding of nature is ignoble; that to pursue an understanding of nature is a worthwhile endeavour in itself. (Lugg, 1968, p. 4)

Given this confidence in the advent of a new civilisation any historical theory of human society could be regarded as redundant or irrelevant. As N.A.S.A. raced to place man on the moon or the brink of supra lunar space and his super human destiny, human nature was identified with insatiable scientific curiosity -- social purposes, uses and values inevitably were to follow. By this time Bruner (1966) had described the human will to learn more comprehensively as rooted in 'curiosity' but also in the drive for 'competence' and 'community' and Schwab (1961) had identified the cultural purposes of teaching science as enquiry with the ideals of 'intellectual autonomy' and 'moral agency' in a participatory democracy.

Associated with advances in the general level of wellbeing in the sixties in Australia came enlarged expectations of personal fulfilment and social justice. The expectation that affluence would evolve into abundance led to a more confident and personal conception of nature. The belief that citizens ought to be free to follow their intelligence and talent to the limits of higher potential, indeed to decide which potential ought to be realised, was at odds with a prescriptive science education constrained within an isolated academic structure. With this implicit recognition of cultural diversity the concept of a singular nature and singular scientific mind became problematic. Quite suddenly Lugg's proclamations of science for citizenship and citizenship for science appear to have a doctrinaire ring, but in what terms could 'man' re-enter the idea of nature in new proposals for general science in the seventies?

The Environment - Natural, Personal and Conventional

Self-conscious humanity re-entered science courses with the Australian Science Education Project (1970-74). The project committed itself to an emphasis on the impact of man on his environment. The 'environment' was understood to be person-centred nature rather than that threatened by technological development. This tension can be felt in relation to the kinds of self-conscious objectives ASEP set itself in the earliest statements of its 'environmental approach' :

2 Students will learn about being members of groups. Most of man's efforts to change the environment and the system of values upon which his behaviour is based arise from group interactions rather than from the needs of individuals.

5 Students will learn about the changes that take place naturally in the natural environment. Only by understanding these changes can a child begin to understand man's impact upon the natural environment.

ASEP Newsletter No. 2, November 1970.

As a 'resource for ASEP teachers' Smolicz wrote a monograph, Man's Coercion of Nature : A Historical and Sociological Perspective, which was written from a critical vantage point outside the psychological tradition of the science curricula. He noted that :

> The modern, Western-inspired civilization, imbued with the Christian anthropocentrism, has utterly lost sight of the ecological truth that man does not simply act on nature from the outside but is himself a part of nature.
>
> (Smolicz, 1971, p. 14)

He clearly saw man re-entering the idea of nature in the early seventies as into the social jungle, the rat race, as territory guarder — where 'fittest', meant 'strongest' and most 'ruthless'. An alienating experience of society was projected by selective examples of science and nature. Science education was seen by Smolicz and other outsiders as a ratification of a kind of natural condonation of ruthless economic selfishness which had become a hopelessness, a despair and the end of significant social effort. If that is what life is like — is naturally like — the promoted ideal of co-operative learning in ASEP is essentially futile.

Smolicz's counter cultural position could hardly be understood or assimilted within a national science program committed to popularising science in schools. Of course the state of nature, to which Smolicz appeals, could be a reactionary idea against change or a reforming idea aganst what was seen as despoilage. The separation of man and nature was not simply the product of modern industry or urbanness but was associated with the problem or the idea of nature as a mechanism. Later the idea of the environment as an internalised regulator of cognitive development and social competence was to be widely criticised because it disempowered teachers or reduced teacher expectations. The essential value of external judgement and human competition were to be reasserted. However the existence of diversity, where once there had been singularity in science courses, could not be reversed by claims that man's unity in nature is established through the common ancestry to the creator, or by appeals to nationalism; although both have been attempted in the 70's.

Many individuals in the ASEP team realised that the relation between man and the physical world must be extremely active, diverse, self-conscious, and in effect continuous before that separation of man from nature is likely to become really problematic. They did see in the social issues of the seventies a quest for personal fulfilment and social justice. However few saw theories of science education as being related to theories of human society. With such hope invested in individual liberation, the problems of social organisation seemed distant or intractable. The allegiance paid to psychological over logical theories when defining the task of science teaching after ASEP, has confirmed for classroom instruction a pseudo independence from social facts which remain oppressive and daunting.

Claims made by outsiders such as Williams (1965) and Roszak (1974) that science had become the dominant force in shaping the psychological and metaphysical basis of our politics (and education) promoted self-esteem amongst science teachers rather than an acknowledgement of concern or responsibility. The vehemence of this criticism can be seen in :

> Would we not still protest that knowing how to dangle us like a puppet on a string is not knowing us at all.
> (Roszak, 1974 p. 24)

When these outsiders spoke on behalf of people faced with social policies derived from some brutally reductionist explanation of human conduct, their views were likely to be discounted as irrelevant to science teaching.

Out of the ways in which we have interacted with the physical world, we have not only formed human nature and an altered natural order, but we have also made societies. If we talk of singular men and singular nature, we can compose a general history of science education, but at the cost of excluding the real and altering social relations. The separation of abstracted man and abstracted nature leads to an intellectual separation in science courses between economics and ecology.

Mirroring Nature - The Epistemology of Science Teaching

Each of the statements quoted from the curriculum writers illustrate an ambiguous reality. On the one hand, the statements arise from each writers' commitment to the social problems of their time - for Turner in the forties it was the sheer absence of any general science program in Victoria; for James and Rowney in the fifties it was the challenge of new knowledge; and for Lugg in the sixties it was the need to produce the new citizen for the scientific age. On the other hand, their statements must also refer back to conventions of scientific language and school practice - to the epistemology of science teaching. Science teachers continue to be strongly influenced by a set of visual metaphors for learning associated with construction of knowledge. (Fawns, 1982).

The notion of 'foundations' of knowledge in science teaching seems to be based on an analogy with the compulsion to believe when staring at things. The epistemological notion of objectivity derives from identification of the reality of a thing with its presence before us, the notion of our priamry relations to objects being analogous to visual perception. This simple correspondence between perception and knowledge is reflected in an important early science method text, Westaway's Science Teaching - what is was, what it is - what if might be where it is written :

> About the real nature of perception - how we come into cognitive contact with reality external to ourselves - even philosophy fails to tell us very much. As for physical science, it simply takes the perceptual world as it finds it, at least as far as its different precepts are mutually consistent, and concerns itself merely to discover its structure and modes of behaviour.
> (Westaway, 1928, p. 388)

The teachers' desire for an 'epistemology', may be simply the most recent product of the dialectical development of such visual metaphors. The dominating metaphor of science teaching as bringing pupils face to face with the object of belief is apparent in Westaway's view of how learning occurs in science classes. Later science teachers have been more concerned with how these natural illustrations are put together in the child's mind. Westaway made the contribution :

> Quite young children often make full and accurate records of their nature study observations; and one great advantage to be derived from nature study as a subject is that a child, having made a definite observation, then has to try to record that observation in words. Once the child has learnt to do this, half the battle is won. A succession of observations, properly classified, is the next step, and this is generally easy.
>
> (Westaway, 1929, p. 113)

Science teaching is identified with training of the inner eye or reducing distortion in the mirror of nature. The task of the science text is then to place within the mirror a special privileged class of representations (like the balanced beam, the precipitation of silver chloride, the dissected rat) - so compelling that the accuracy of the explanation that accompanies them cannot be doubted. These privileged foundations of knowledge, and the discipline which directs us towards them, 'science', have become the psychological and philosophical foundation of science teaching.

> Science is the best teacher of accurate, acute, and exhaustive observation of what is; it encourages the habit of mind which will rest on nothing but what is true; truth is the ultimate and only object, and there is the ever-recurring appeal to facts as the test of truth.
>
> (Westaway, 1929, p. 16)

Manifest in ASEP units is an early criticism of the notion of the science teaching as mirroring nature and thus putting truth in the eye. It is argued that it is not possible to isolate the essential paradigms of scientific knowledge for school courses without final knowledge of the whole field within which these paradigms occur, a state which is difficult if not impossible to now attain. Neither will we be able to substitute the notion of 'accurate representation' of nature in science texts for that of successful science teaching since our choice of paradigms should be dictated by an understanding of science teaching rather than the practice being 'legitimated' by a rational reconstruction out of paradigms.

Coming to understand a science course is more like getting involved in an argument than following a demonstration. Teachers and their pupils play back and forth between guesses about how to characterise particular statements or events, and possible relationships between the parts of the whole situation, until gradually they feel at ease with what was hitherto strange.

The notion of science (new knowledge) as a conversation rather than a structure erected upon foundations fits well with this holistic notion of science teaching. From this point of view, the line between 'structural' and 'culture' may not be a matter of the differences between the 'science of nature' and the 'science of man'. The difference may be purely one of familiarity. We will speak of structures where we understand perfectly well

what is happening but want to modify them in order to extend, teach, or otherwise ground knowledge. Where we can get a set of rules for rational agreement about curricular content, it is not because we have discovered something about the nature of human knowledge, but simply because when a practice has continued long enough, the coventions that make the practice possible and which permit a consensus on how to divide it into parts are relatively easy to isolate. The ASEP units, with their common-language titles, embody doubts about the claims that the procedures employed to select what paradigms of nature to teach differ in meaningful ways from the procedures for attaining agreement on practical or aesthetic matters.

Historically, the autonomy of science and science teaching from religion and politics has been linked with the image of scientific theory as the Mirror of Nature (Rorty, 1980). The distinctiveness of science is no longer dependent upon this image. For science teaching, however, the transparency of what is taught, to nature or 'reality' remains important in arguments for particular paradigms over others in science courses. The key words textbook teachers have used in describing their general science courses still tend to take their significance from their representative character in 'Physics', 'Chemistry' and 'Biology' rather than from other words (Fawns, 1982). The corollary of this is that the key words in science courses acquired their privileged place from their transparency to nature rather than from the people who use them.

Textbook authors have often argued that their new proposal is more 'scientific' than its predecessor, pointing to inefficiencies and inaccuracy in former approaches rather than to enunciation of the new. As an example :

> The major criticisms of conventional curriculum have been (1) high school science courses do not reflect science as science is known by scientists, either in content or method; and (2) learning is inefficient and students are unable to make intellectual use of what they learn.
>
> (Hurd, 1969, p. 47)

Whilst the textbook writers quoted here have sought to establish a new purpose for science education, often challenging conventions of language and classroom practice in the process, they have all been forced to work through these conventions because they are the historical instruments by which reality is created. Between the public confidence these writers have expressed in science education and their brooding reflections upon the conventions, we live our professional lives. We, like them, have come to know that the conceptions of nature and science are as varied and variable as the changing condition of a human world.

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